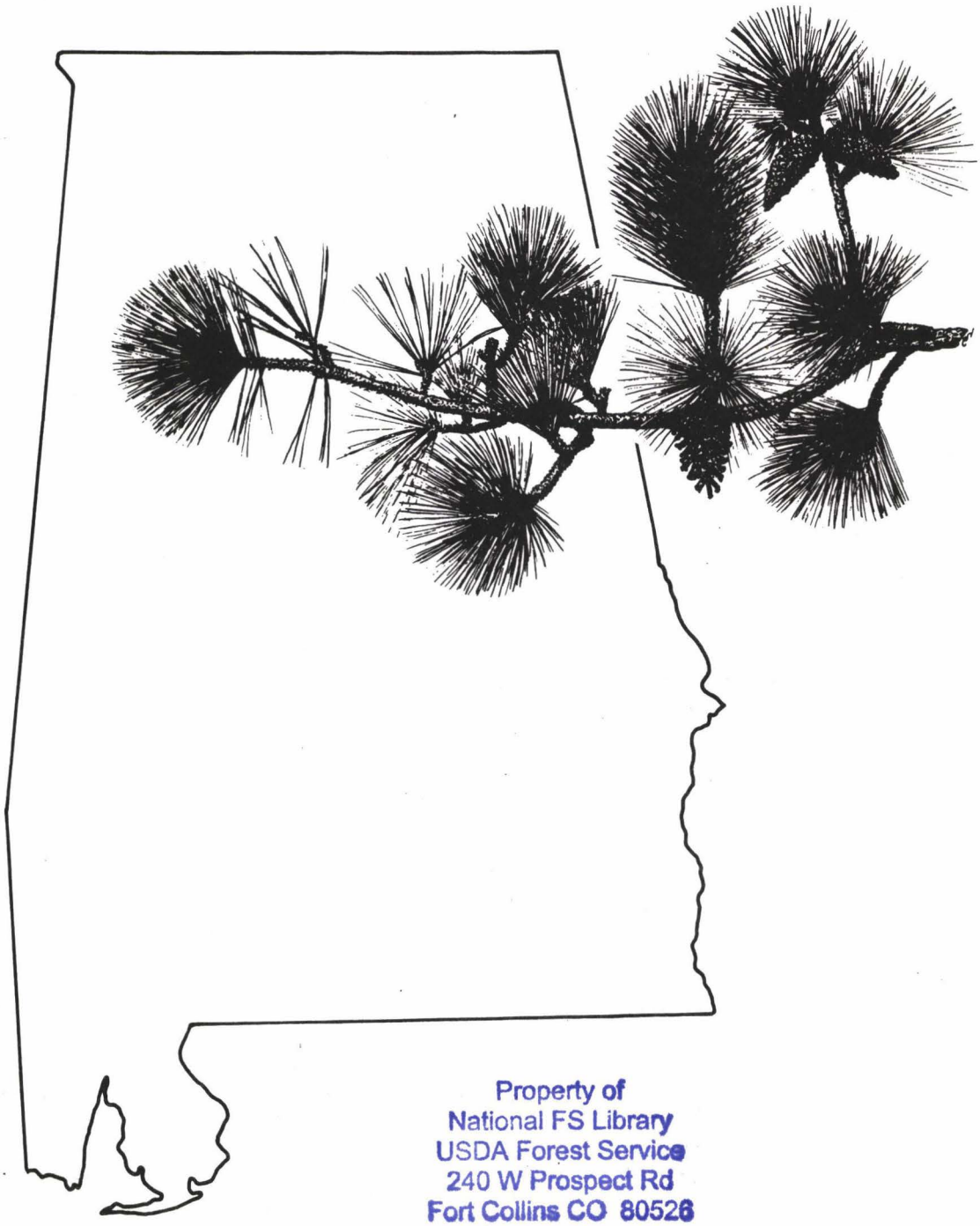
R-08 MISC
SD11
.R8

TMR REFERENCE COPY

United States
Department of
Agriculture

Forest Service
Southern Region
Southern Forest
Experiment Station

Demonstrations of Longleaf Pine Management and Technology in Alabama



Property of
National FS Library
USDA Forest Service
240 W Prospect Rd
Fort Collins CO 80526

Experimental forests have served as outdoor laboratories to test hypothesis in the development of southern forest management technology. The Escambia Experimental Forest is administered by the Southern Forest Experiment Station, USDA-Forest Service on properties leased from T. R. Miller Mill Company. It has contributed significantly to our understanding of longleaf pine.

The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or services to the exclusion of others which may be suitable.

PREFACE

Originally, there were thought to be about 60 million acres of longleaf pine growing in the South. By 1955, acreage had been reduced to just over 12 million. From 1955 to 1985, an estimated 8.5 million acres were converted to other pines or uses, bringing the present total to just under 4 million acres.

Most folks who know southern pines admire the stately longleaf pine with its many attributes, but few have been willing to reforest it after harvest. Why this paradox? Primarily because of the concepts developed early that longleaf pine was very difficult to regenerate and a slow grower once regenerated. Those concepts have been perpetuated through the years. Although these concepts were valid in the 1920's and 30's, they are not valid today.

In the early years of southern forest management, specific technology for regenerating longleaf pine was not available. Many attempted to regenerate longleaf using the emerging regeneration technology developed for less demanding species such as loblolly and slash pines with disappointing results. Today we have the technology for regenerating longleaf pine that will produce good results when used properly. The future of the species depends upon overcoming the original bias established in the early years which have persisted to the present.

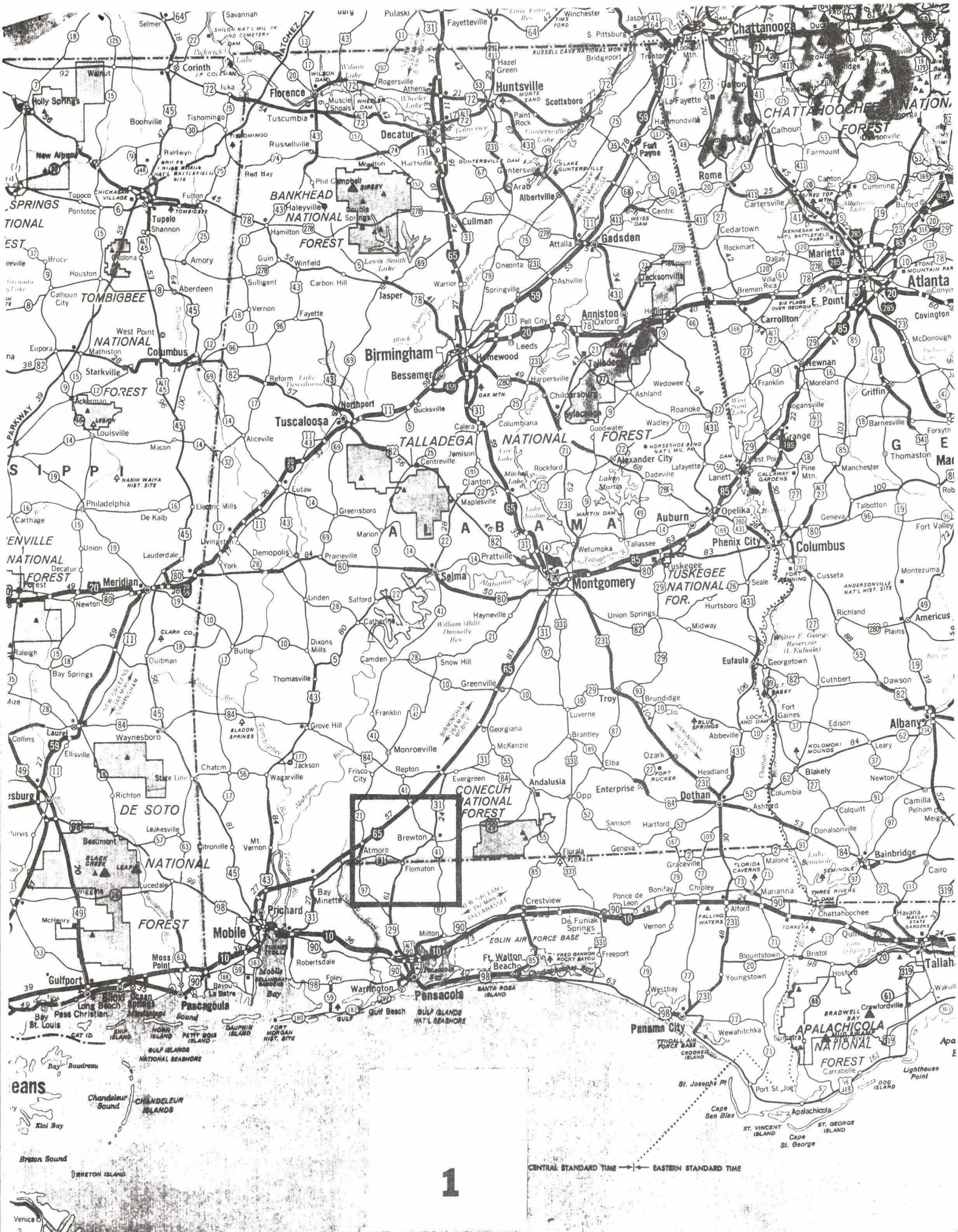
This series of demonstrations has been developed to help better understand longleaf pine and the very exacting regeneration requirements it has. The demonstrations have been organized so they can be visited on a "self-guided" basis or with an informed discussion leader. Those seriously interested in longleaf pine culture need to become knowledgeable of the technology developed specifically for this species.

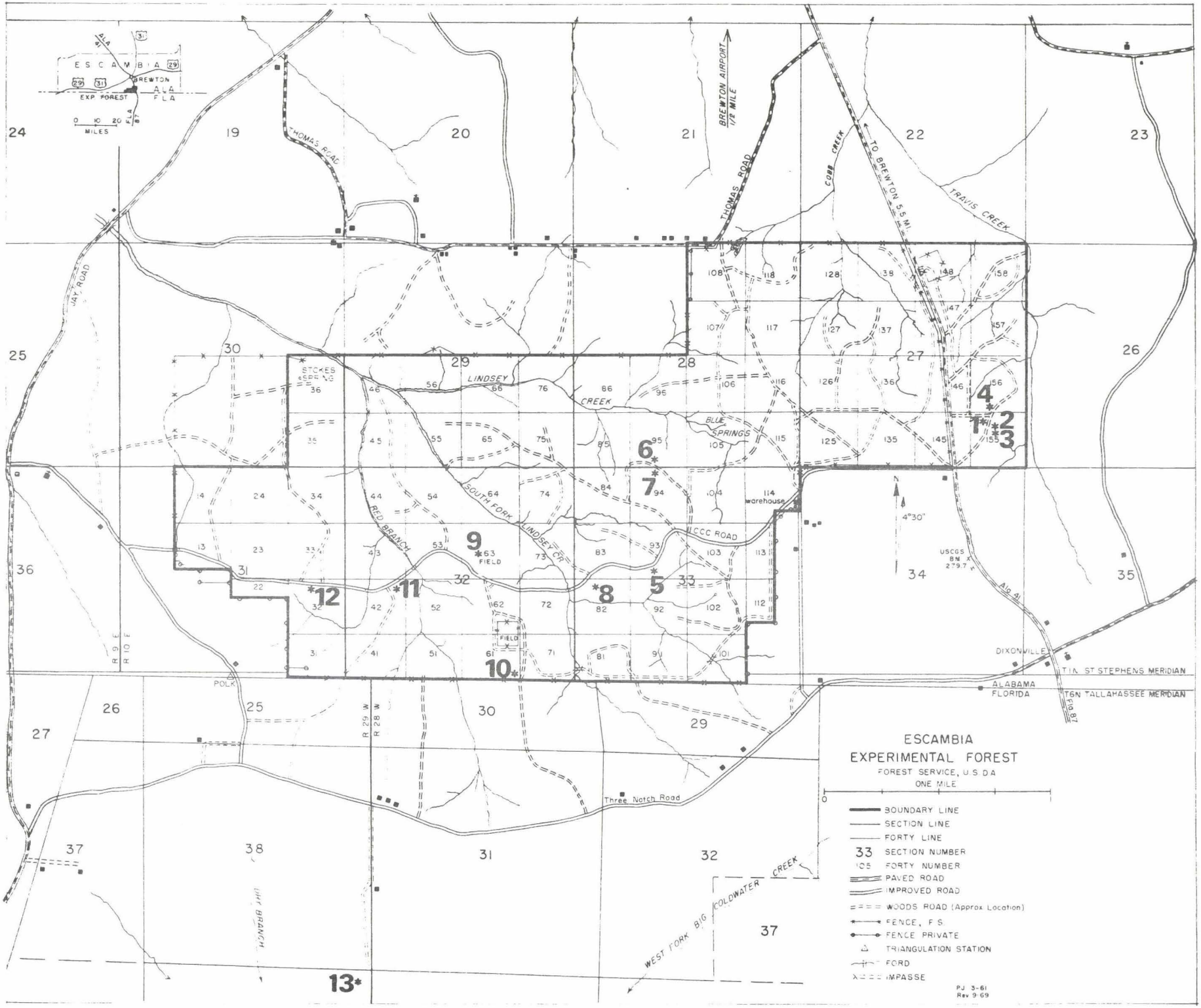
A suggested reading list is included in the handout to help you get started.

TABLE OF CONTENTS

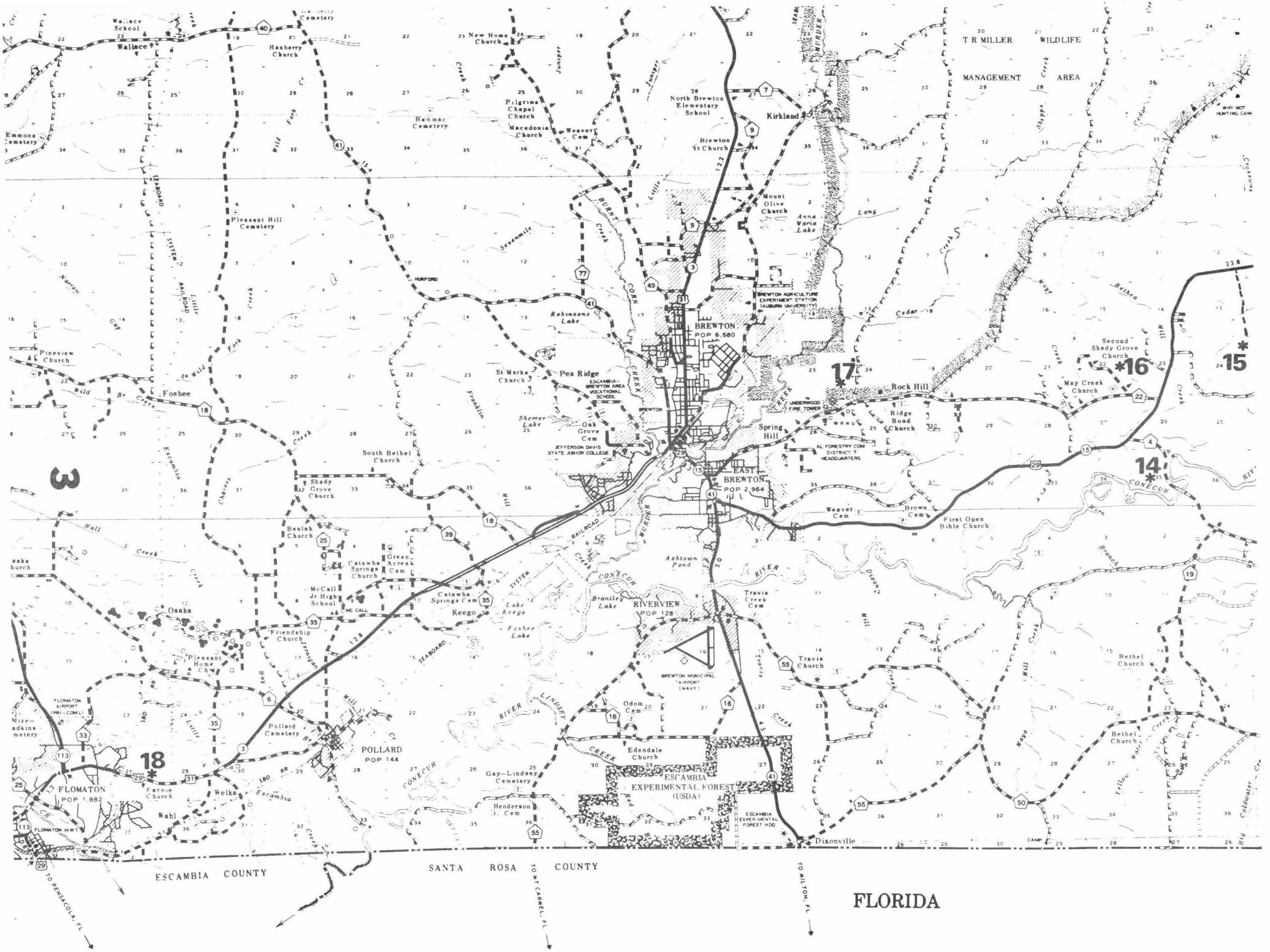
Page

State Map....1
Escambia Experimental Forest Map (Stops 1-13)....2
Escambia County Alabama Map (stops 14-18)....3
Key to Management Activities....4
Natural Regeneration Summary....5
Stop 1....7
Nursery Culture of Bare-Root Seedlings Summary....8
Stop 2....13
Stop 3....15
Stop 4....16
Growth and Yield Summary....17
Stop 5....19
Stop 6....21
Stop 7....22
Stop 8....24
Stop 9....26
Stop 10....28
Stop 11....29
Stop 12....30
Planting Bare-Root Seedlings Summary....31
Stop 13....36
Stop 14....37
Stop 15....38
Stop 16....39
Stop 17....41
Stop 18....42
Suggested Reading....43


Selmer
Savannah
Pulaski
Fayetteville
Winchester
Jasper
Chattanooga
Corinth
Florence
Huntsville
Scottsboro
Holly Springs
Walnut
Boonville
Tishomingo
Tuscumbia
Decatur
Russellville
Red Bay
New Albany
Fulton
Tupelo
Shannon
Pontotoc
Topoco
Bruce
Houston
Calhoun City
Aberdeen
Amory
Winfield
Carbon Hill
Jasper
Vernon
Fayette
Sulligent
Hamilton
Haleyville
Double Springs
Phil Campbell
Sibley
Bankhead National Forest
Cullman
Oneonta
Ashville
Springville
Warrior
Gadsden
Attalla
Albertville
Guntersville
Arab
Rome
Cedartown
Rockmart
Dallas
Marietta
Atlanta
Jacksonville
Anniston
Oxford
Pell City
Leeds
Birmingham
Homewood
Bessemer
Talladega
Columbus
West Point
Mathiston
Starkville
Eupora
Louisville
Ackerman
Tombigbee National Forest
Tuscaloosa
Northport
Bucksville
Columbiana
Calera
Chelsea
Sylacauga
Talladega National Forest
Harpersville
Chelsea
Ashland
Wedowee
Roanoke
Goodwater
Wadley
Alexander City
Lafayette
Dadeville
Lanett
West Point
La Grange
Newnan
Griffin
Franklin
Moreland
Carrollton
Villa Rica
Bremen
Heflin
Jemison
Centreville
Clanton
Maplesville
Rockford
Eutaw
Aliceville
Macon
Philadelphia
De Kalb
Electric Mills
Greensboro
Carthage
Union
Lauderdale
Livingston
Demopolis
York
Prairieville
Marion
Selma
Prattville
Montgomery
Wetumpka
Tallassee
Auburn
Opelika
Phenix City
Columbus
Tuskegee National Forest
Meridian
Newton
Linden
Safford
Catherine
Hayneville
Union Springs
Hurtsboro
Midway
Seale
Eufaula
Georgetown
Cuthbert
Dawson
Albany
Richland
Americus
Plains
Montezuma
Fort Valley
Talbotton
Geneva
Raleigh
Bay Springs
Quitman
Clark Co.
Butler
Dixons Mills
Camden
Snow Hill
Thomasville
Greenville
Troy
Brundidge
Luverne
Brantley
Abbeville
Clio
Blue Springs
Fort Gaines
Edison
Leary
Blakely
Newton
Laurel
Ellisville
Waynesboro
Collins
Grove Hill
Georgiana
McKenzie
Monroeville
Franklin
Bladon Springs
Tombigbee River
Alabama River
Chatom
State Line
Richton
Wagarville
Jackson
Frisco City
Repton
Evergreen
Andalusia
Opp
Enterprise
Ozark
Fort Rucker
Dothan
Headland
Ashford
Columbia
Colquitt
Camilla
Pelham
Meigs
Donalsonville
Samson
Hartford
Geneva
Florala
Florala
Graceville
Malone
Seminole
Bainbridge
Cairo
Bonifay
Chipley
Marianna
Alford
Chattahoochee
Havana
Quincy
Tallahassee
Crestview
Ponce de Leon
De Funiak Springs
Vernon
Falling Waters
Three Rivers
Torreya
Blountstown
Bristol
Hosford
Youngstown
Westbay
Panama City
Wewahitchka
Tyndall Air Force Base
Crooked Island
Apalachicola National Forest
Carrabelle
Sumatra
Crawfordville
Tallahassee
Wakulla
Lighthouse Point
St. Joseph Pt
Port St. Joe
Cape San Blas
Apalachicola
St. Vincent Island
St. George Island
Cape St. George
Dog Island
Prichard
Mobile
Bay Minette
Mt. Vernon
Citronelle
Leakesville
Lucedale
Wiggins
McHenry
Besumont
Gulfport
Biloxi
Ocean Springs
Pascagoula
Bay St. Louis
Pass Christian
Long Beach
Gulf Islands National Seashore
Ship Island
Horn Island
Petit Bois Island
Dauphin Island
Fort Morgan Hist. Site
Mobile Bay
Mobile Bay Causeway
Robertsdale
Foley
Gulf Shores
Orange Beach
Perdido Bay
Warrington
Pensacola
Santa Rosa Island
Gulf Beach
Milton
Eglin Air Force Base
Ft. Walton Beach
Fred Gannon Rocky Bayou
Choctawhatchee Bay
Freeport
Brewton
Atmore
Flomaton
Conecuh National Forest
Escambia River
Escambia Bay
Florida Caverns
Falling Waters
Three Rivers Dam
Lake Seminole
Florida
Alabama
Georgia
Mississippi
Louisiana
Tennessee
Gulf of Mexico
Chandeleur Islands
Chandeleur Sound
Breton Sound
Breton Island
Eloi Bay
Boudreau Bay
Venice
Central Standard Time
Eastern Standard Time


ESCAMBIA EXP. FOREST
ALA
FLA
BRENTON
0 10 20 MILES
BRENTON AIRPORT 1/2 MILE
THOMAS ROAD
TO BRENTON 5.5 MI.
COBB CREEK
TRAVIS CREEK
JAY ROAD
THOMAS ROAD
STOKES SPRING
LINDSEY CREEK
BLUE SPRINGS
SOUTH FORK LINDSEY CR.
RED BRANCH
LCCC ROAD
warehouse
FIELD
USCGS BM X 279.7 ft
4°30'
Alg 41
DIXONVILLE
POLK
R 9 E
R 10 E
R 29 W
R 28 W
T1N ST STEPHENS MERIDIAN
T6N TALLAHASSEE MERIDIAN
ALABAMA
FLORIDA
Three Notch Road
DRY BRANCH
WEST FORK BIG COLDWATER CREEK
ESCAMBIA
EXPERIMENTAL FOREST
FOREST SERVICE, U.S.D.A.
ONE MILE
BOUNDARY LINE
SECTION LINE
FORTY LINE
33 SECTION NUMBER
105 FORTY NUMBER
PAVED ROAD
IMPROVED ROAD
WOODS ROAD (Approx Location)
FENCE, F.S.
FENCE PRIVATE
TRIANGULATION STATION
FORD
IMPASSE
PJ 3-61
Rev 9-69

2


BREWTON
POP 6,680
EAST BREWTON
POP 2,964
RIVERVIEW
POP 128
POLLARD
POP 144
FLOMATON
POP 1,882
Pea Ridge
Rock Hill
Spring Hill
Kirkland
Foshee
Wallace
Wallace School
Hanberry Church
Pleasant Hill Cemetery
Pineview Church
St Marks Church
Oak Grove Cem
South Bethel Church
Shady Grove Church
Beulah Church
Catawba Springs Church
Green Acres Cem
McCall Jr High School
Catawba Springs Cem
Keego
Osaka
Friendship Church
Pleasant Home Church
Pollard Cemetery
Ernnie Church
Welka
Wahl
Gay-Lindsey Cemetery
Henderson Cem
Edendale Church
Odom Cem
Travis Church
Travis Creek Cem
Bethel Church
Weaver Cem
Brown Cem
First Open Bible Church
Ridge Road Church
May Creek Church
Second Shady Grove Church
Mount Olive Church
Brewton 33 Church
North Brewton Elementary School
Pilgrim Chapel Church
Macedonia Church
New Home Church
Hammac Cemetery
Emmons Cemetery
Robinsons Lake
Anna Maria Lake
Sherrer Lake
Brantley Lake
Lake Keego
Foshee Lake
Ashtown Pond
Brewton Municipal Airport (Navy)
Flomaton Airport (Pri-Com)
Flomaton MWT
Escambia Experimental Forest (USDA)
Escambia Experimental Forest HDQ
Escambia-Brewton Area Vocational School
Jefferson Davis State Junior College
Brewton Agricultural Experiment Station (Auburn University)
Underwood Fire Tower
WKNU
Al Forestry Com District 7 Headquarters
T R Miller Wildlife Management Area
Why Not Hunting Camp
Dixonville
Camp
3
17
16
15
14
18
ESCAMBIA COUNTY
SANTA ROSA COUNTY
FLORIDA
To Pensacola, FL
To Nt Carmel, FL
To Milton, FL
Seaboard System Railroad
Conecuh River
Escambia River
Murder Creek
Burnt Corn Creek
Sevenmile Creek
Juniper Creek
Wild Fork Creek
Little Escambia Creek
Franklin Creek
Chavers Creek
Hall Creek
Narrow Gut Creek
Lindsey Creek
Travis Creek
Mill Creek
Long Branch
Cedar Creek
Bethea Creek
Yellow Water Creek
Coldwater Creek
Hwy 29
Hwy 41
Hwy 31
Hwy 55
Hwy 50
Hwy 97
Hwy 180
Hwy 4
Hwy 6
Hwy 7
Hwy 9
Hwy 15
Hwy 16
Hwy 18
Hwy 19
Hwy 22
Hwy 25
Hwy 33
Hwy 35
Hwy 39
Hwy 49
Hwy 77
Hwy 113

KEY TO MANAGEMENT TREATMENT/ACTIVITY DEMONSTRATED

Demonstrated Treatment	Demonstration Stop Number																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Unevenaged Management				X														
Benomyl		X	X															
P.T. Ectomycorrhizae		X																
Planting Bare-Root Seedlings		X	X										X	X	X	X	X	
Comparison of Species									X				X	X				
Natural Regeneration	X			X		X	X				X	X						
Growth and Yield				X	X							X	X	X	X	X		
Precommercial Thinning									X			X						
Product Selection										X								
Site Preparation	X			X		X	X	X			X		X	X	X	X		
Site Evaluation					X								X	X				
Virgin Stand																		X
Prescribed Fire	X			X		X	X	X			X							X
Effects of Brown-Spot Disease		X	X															
Pest Management		X	X						X									
Direct Seeding									X									

NATURAL REGENERATION

Like all of the original stands, longleaf can be reproduced through natural regeneration methods. A recommended shelterwood system has been developed and may be the best for many ownerships because it is less expensive than clearcut, site prepare, and plant methods. Any natural regeneration method for longleaf pine must provide at least four essential elements: (1) sufficient desirable parent trees, well distributed so that they provide an adequate supply of seed throughout the regeneration area; (2) midstory, understory, and seedbed conditions favorable for the establishment, survival, and growth of seedlings; (3) protection from livestock, wildfire, brown-spot disease, and other hazards; and (4) complete release from overstory and brush competition after adequate stocking has been secured.

The shelterwood method works best if applied after steps have been taken to prepare the stand for regeneration before the harvest cut. If overstory density exceeds 70 to 80 square feet of basal area per acre, a preparatory cut should be made. This cut should be made about 5 years in advance of the seed cut, leaving 60 square feet of basal area on the poorest sites and 70 square feet on the better sites. The preparatory cut is essentially a thinning, mostly from below, which leaves the largest trees of good quality with ample room to enlarge their crowns. Hardwood competition should be controlled through harvest, if merchandable for products or fuel, and by prescribed burning, chemicals, or a combination of both. This control should be done at or before the seed cut or promptly after.

The seed cut should leave 25 to 30 square feet of basal area per acre of dominant or codominant seed trees showing signs of fruitfulness. Those trees should be evenly distributed over the area, more than 30 years old, 10 inches or more in d.b.h., and above average in height, form class, and volume. Several years may elapse between the seed cut and the establishment of adequate regeneration. But this period isn't totally unproductive. Parent trees generally experience accelerated growth that equals about two-thirds of the per acre volume growth occurring before the cut. During this period, hardwoods should be kept under control by timely prescribed burns.

Also, after the seed cut, an annual forecast of seed crops should be made for the purpose of timing the final seedbed preparation treatment before seedfall. Counting conelets in the spring with the aid of binoculars will give good estimates of the current year's cone crop, and a count of flowers at the same time may give an indication of the potential cone crop 18 months hence. These counts should be made in late April or early May, just before female flowers are obscured by new foliage. A regeneration survey should be made during first winter after the seed cut to determine stocking of advance reproduction. These surveys are repeated periodically to assess status of pine reproduction in the regeneration area.

The amount of seed necessary to ensure a new stand depends on the condition of the seedbed, predator pressure, the soil, understory conditions and existing seedling stocking. Ideally, at least 50,000 seeds per acre are needed on a well-prepared seedbed to get a good stand of seedlings established. This requires roughly 1,000 cones per acre or 35 to 50 cones per seed tree. Timing a

prescribed burn or light mechanical scarification up to 3 months before seedfall (normally mid-October through November) is strongly recommended.

Once an adequate seedling stand is established, the overstory should be harvested, ideally at seedling age 2, but before many seedlings begin height growth. The usual criterion for an adequate seedling stand is 6,000 or more 1-year-old seedlings per acre. This number will absorb logging mortality of up to half the stand and still provide enough survivors that the superior 10 to 20 percent of the seedling stand will provide about 500 crop seedlings per acre. Regardless of age, rapid height growth does not start until the seedlings are at about 1-inch RCD at the groundline.

ALABAMA TOUR - STOP NO. 1

LONGLEAF PINE NATURAL REGENERATION

This stand demonstrates successful natural regeneration of longleaf pine by using the Shelterwood system.

LOCATION: Study plot is located in compartments 145 & 155 of the Escambia Experimental Forest. Site is 1.1 mile west of headquarters of the experimental forest.

CONTACT: Escambia Experimental Forest, U.S. Forest Service, Rt. 3, Box 197B,

Brewton, AL 36426 Tel. (205) 867-3942

Research Work Unit (RWU) 4105, Southern Forest Expt. Sta., U. S. Forest Service, Devall St., Auburn Univ., Auburn, AL 36849 Tel. (205) 826-8700.

SIZE OF UNIT: Total of 42 acres

YEAR OF SEEDCUT: 1973 & 1977. The rapid growth of residuals after first cut raised density from 30 to 45 sq. ft./acre so second seed cut needed.

YEAR OF REMOVAL CUT: 1981

STOCKING (1-88): 3000 seedlings/acre (1975 seed crop). 71% of sample milacres were stocked. Crop tree height = 12.5' (Tallest well-distributed 250 trees/acre).

CULTURAL HISTORY:
1) Fall seedbed burn - 1975
2) Hardwood control - 1972, 1987 (injection)
3) Spring burn - 1979
4) Winter burns - 1983, 1988 (for brush control)

SUMMARY

The Shelterwood system can be used to regenerate longleaf pine naturally at low cost, and with a high degree of success if specific and necessary cultural measures are properly timed and executed.

NURSERY CULTURE OF BARE-ROOT LONGLEAF PINE SEEDLINGS

Introduction

Reforestation with longleaf has historically been difficult and avoided because of combined problems of INFERIOR SEEDLING QUALITY protracted slow growth in the characteristic "grass" stage, unacceptable levels of competing vegetation, and the extreme susceptibility of seedlings to brown-spot foliage blight (Scirrhia acicola) during the grass stage. Seedlings are considerably less susceptible to the disease after they grow out of the grass stage. Initiation of height growth of longleaf seedlings is apparently correlated with stem diameter and seedling vigor. Consequently, improved seedling quality in the nursery reduces both the duration of the grass stage and the effects of brown-spot foliage blight.

Longleaf pine reforestation has recently gained considerable attention, particularly since many off-site plantings of slash and loblolly pines on deep sands have either stagnated in growth or succumed to fusiform rust. Extensive research studies have recently identified key components of longleaf seedling quality and developed an integrated nursery management approach to produce higher quality seedlings for increased field survival and growth. Biological, chemical, and cultural practices are coordinated to increase seedling root development, ectomycorrhizae, and stem diameter; decrease nursery and field planting pest problems; and maintain seedling quality beyond the nursery packing shed. Soil fumigation, sowing date, seedbed density, and seedling handling and storage can affect longleaf seedling quality significantly. Maximum potential increases in seedling quality are obtained by inoculating prefumigated seedbeds with the ectomycorrhizal fungus Pisolithus tinctorius (Pt), precision sowing longleaf seed for optimum seedling spacing and density, and lateral and horizontal root pruning for increased feeder root and ectomy- corrhizae development. Root treatment of longleaf seedlings, either at the nursery or planting site, with the fungicide benomyl has controlled brown-spot disease, along with increasing tree survival and growth in field plantings. Failure to properly use and coordinate these management practices can have significant negative effects on seedling quality and field performance.

Fumigation

Practically all southern nurseries utilize soil fumigation as a standard component of seedling production to control weeds, certain insects, nematodes, and soil-born diseases, such as Cylindrocladium root rot (Cylindrocladium sp.) or charcoal root rot (Macrophomina phaseolina). Soil fumigation is also effective for the control of soil-borne diseases, such as Rhizoctonia blight (Rhizoctonia solani), a very serious disease on 1-0 longleaf pine seedlings in southern bare-root nurseries. Both Rhizoctonia blight and brown-spot can also be introduced into nurseries through unfumigated mulch, particularly longleaf pine straw. To control these and other potential nursery pest problems, both soil and mulch should be fumigated.

Soil fumigation is required for most nursery soils prior to seedbed inoculation with Pt. To maximize the benefit of artificial Pt inoculation, all soil organisms, including the naturally occurring ectomycorrhizal fungi, must be

eliminated, at least temporarily. Spring fumigations of soil and mulch material followed as soon as possible by Pt inoculation and seed sowing have provided the most consistent and effective artificial inoculation results. Preliminary results obtained from a study at Taylor State Nursery, S.C., indicate that fall fumigated nursery seedbeds and fall sown longleaf pine seedlings can be successfully inoculated with Pt the foollowing spring. Consequently, the close synchronization between soil fumigation and Pt inoculation observed for other pine species may not be as critical for longleaf pine.

Sowing Dates

Generally, longleaf pine seedlings planted in the fall are larger by lifting date than are similarly treated spring sown seedlings. Spring sown seedlings lose 2 to 4 weeks of optimum growing conditions during germination and may be subjected to high temperatures before becoming well established. Fall sown seedlings germinate in the fall, initiate rapid growth in early spring, and are large enough by late spring to withstand the heat. The extended growing regime, in combination with other practices, provides additional time for increased root collar diameter growth and root development. Currently, Pt inoculation of longleaf seedlings is operationally designed for spring fumigation, inoculation, and sowing dates. Rercent research results suggest the possibility of inoculating fall sown seedlings during the following spring. Also, soil conditions during the fall are usually better for soil fumigation, providing more effective results. A major disadvantage of fall planting may be demonstrated by abnormally cold winters that have caused significant damage to fall seeded longleaf pine in several southern nurseries.

Pt Ectomycorrhizae

Numerous studies have shown that effective Pt ectomycorrhizal inoculation improves longleaf seedling quality by increasing the amount of fibrous feeder roots and ectomycorrhizae. Standard nursery run longleaf seedlings often have a relatively low ectomycorrhizal occurrence with very few fine feeder roots and secondary lateral roots when harvested. Artificial inoculation with Pt provides longleaf seedlings with better developed root systems and ectomycorrhizae, and larger stem diameters which result in improved field performance.

Bare-root nursery seedbeds and container mixes can be inoculated by several different techniques using various types of commercial Pt inoculum. The most effective and consistent results are achieved when the inoculations are preceded by soil and mulch fumigation (preferably spring fumigation with MC-2). The types of commercial Pt inoculum that are currently available are vegetative inoculum and spore pellets, spore-encapsulated seeds, and bulk spores. A bare-root nursery seedbed applicator has been developed to apply Pt vegetative inoculum prior to sowing. This machine applies the inoculum in bands beneath seedling rows at desired depths for maximum inoculum effectiveness and efficiency.

Bulk spores can be sprayed, drenched, or dusted onto seedbeds in bare-root nurseries. Spore pellets can either be incorporated into seedbed soil, or they can be broadcast on the soil surface and lightly covered with soil. Spore pellets have been operationally applied at several nurseries with a standartd fertilizer spreader. Spore-encapsulated seeds are sown by conventional methods. A major disadvantage of the Pt spore inoculum is the absence of a means of either determining or controlling spore viability. Consequently, Pt ectomycorrhizal

development has been considerably less consistent and effectivc with spore inoculum than with vegetative inoculum.

Seedbed Density

Numerous research studies have repeatedly shown the effects of seedbed density on diameter growth and quality of longleaf pine seedlings in bare-root nurseries. Seedbed densities exceeding 15 seedlings/ft^2 result in lower quality seedlings with substandard root collar diameters, feeder root and ectomycorrhizae development, and shoot:root ratios, providing inadequate field survival and growth. Seedbed densities, ranging between 10 to 15 seedlings/ft^2, are considered most effective for longleaf pine seedling production in southern bare-root nurseries. Seedbed densities less than 10 seedlings/ft^2 do not efficiently utilize the seedbed and, consequently, are not cost effective for operational use. The demonstrated effect that density has upon longleaf seedlings is a result of plant competition for nutrients, water, air, and light, and obviously has a direct effect on seedling quality. Reduced seedbed densities (i.e., 10 to 15 seedlings/ft^2) coordinated with additional nursery cultural practices, such as row seeding, precision sowing, and lateral and horizontal root pruning, will provide significant increases in longleaf pine seedling quality.

Precision Seed Sowing

Only recently has the technology become available to nursery managers in the United States to precision sow forest tree seed. Several types of precision seed sowers are available. These vacuum sowers operate by pulling a partial vacuum through specifically sized and spaced holes on a rotating drum or disk, which pick up, then drop individual seeds. Adjustments to tractor speed, drum or disk rotation speed, and vacuum pressure can provide a wide range of highly precise sowing rates. Very precise seed spacing and density are possible when using small to medium seeds with high purity and germination. Until 1987, longleaf seed had never been sown with a precision sower. Characteristic low seed purity and germination potential of most longleaf seedlots are major disadvantages in control of both density and spacing. However, with good quality seed (greater than 90% purity and 75% germination), sowing rates can be adjusted to maintain desired lower densities and precise spacing. Maintaining sufficient spacing between individual seedlings in bare-root nurseries significantly affects seedling size and quality.

In addition to low purity and germination, the large irregular shape of the longleaf seed and its permanently attached wing stubs are primary limiting factors affecting precision sowing. The seeds bridge across each other in the seed hopper, and without some means of breaking this bridge, they do not maintain sufficient contact with the drum to be picked up by the vacuum holes, resulting in skips in the seed spacing within rows. Conversely, it is possible for more than one seed to be picked up by each vacuum hole when several bridged, winged seeds are contacted. Techniques are being tested involving the mechanical agitation of the seed in the hoppers and the "singulation" of the seed on the vacuum holes. Potential benefits to longleaf pine nursery seedling management derived from improved control of seedbed density and spacing merit continued work to develop a suitable machine for the precision seed sowing of longleaf pine. A major disadvantage of all vacuum precision seed sowers is slow rate of operation, as compared with other types of seed sowers. This negative factor will require

considerable additional effort to allow the large scale adoption of precision seed sowers in large volume seedling production nurseries in the southern U.S.

Root Pruning

Lateral and horizontal (undercutting) root pruning significantly increases longleaf pine seedling quality when properly applied. At the proper depth and distance from seedlings, root pruning stimulates formation of compact root systems, conditions the root system to the shock it experiences at lifting, and increased ectomycorrhizal development. Injury of the root tips initiates greater carbon allocation to the root system, which causes the increased root growth. This practice increases the amount of feeder roots proximal to the seedling tap root, effectively increasing the amount of ectomycorrhizae and feeder roots that will be retained with the seedling during lifting and handling. With longleaf pine seedlings, it is particularly important to develop a compact root system with adequate secondary roots, feeder roots, and ectomycorrhizae. Following root pruning, seedlings should be irrigated to resettle the seedbed surface and avoid desiccation of the roots.

Seedling Handling and Storage

Special care must be taken during all stages of seedling handling to maintain sufficient root systems and ectomycorrhizae. Feeder roots can be ripped off and left behind in seedling beds during lifting, desiccated in storage, or cut off prior to field planting. For sustained seedling quality, lifting and handling techniques must be modified to minimize damage. Stripping of roots adds severe negative impacts on seedling field performance. Full bed seedling harvesters are less destructive than single- or double-row lifters. Condition of the root systems should be checked during the entire lifting process; even slight reductions in tractor speed can greatly reduce damage to the roots as seedlings are lifted. During transfer of seedlings from the field to the packing room and at all other times when seedlings are handled, avoid drying of the roots by exposure to wind and sun. The procedure by which seedlings are packed influences their ability to endure storage and survival in field plantings. Longleaf pine seedlings deteriorate rapidly with significant reductions in field survival if stored for any extended time periods. Cold storage is vital to reduce seedling respiration. Studies comparing packing materials have determined that seedling survival is significantly improved when peat moss, clay, or inert moisture absorbents are used rather than hydromulch. Seedling quality is affected by any one or more limiting factors. Proper seedling handling and storage is equally important to growing high quality seedlings.

Benomyl Root Treatment

The systemic fungicide benomyl is recommended for use as a seedling root treatment prior to packing at the nursery or planting at the forestation site for the control of brown-spot needle blight, caused by the fungus Scirrhia acicola, on longleaf pine. One single fungicide root treatment has provided effective brown-spot disease control in longleaf pine plantations for 3 years. Additional significant tree survival benefits have been obtained on benomyl-treated seedlings in field plantings.

The longleaf pine seedling roots are treated in a benomyl-kaolinite clay-water mixture consisting of 1 pound benomyl (Benlate - 50 WP) and 9.5 pounds of dry kaolinite clay with an adequate amount of water to form a semi-plastic clay slurry that will readily adhere to the moistened seedling roots. For consistent, effective results, continuous agitation should be maintained in the mixing tank, and the seedling roots should be sprayed with a relatively low pressure garden hose type system rather than root dipping in the mixture. This fungicide-clay mixture represents a dosage rate of 5 percent benomyl active ingredient (wt/wt). No surfactant or spreader-sticker is needed with this treatment. Do not apply the mixture to the seedling foliage. Avoid exposing the treated roots to abnormally high temperatures (i.e., above 90 degrees F), freezing temperatures, or to excessive drying conditions. Use special care to avoid loss of the benomyl-kaolinite clay mixture from the treated roots during seedling packaging, storage, transport, and field planting. The seedling roots cannot be watered or treated with additional moist pesticide treatments following the benomyl treatment. The kaolinite clay is the most effective carrier for the benomyl fungicide. Other seedling packing materials, such as peat, hydromulch, and water gels, have provided less effective results. To be effective, the fungicide must remain in contact with the seedling roots at a lethal concentration for an extended time period (i.e., 2 to 3 years).

Conclusion

The effects of various nursery cultural, biological, and chemical practices on longleaf pine seedling quality have been repeatedly demonstrated. Two of the more innovative and promising recent developments are the Pt ectomycorrhizae application and the benomyl fungicide root treatment. These two unique practices should be closely evaluated for practical application in longleaf pine seedling production. However, sustained quality longleaf pine seedling production and successful forestation require the continuous integrated application of all the above related nursery management and forestation practices.

ALABAMA TOUR - STOP NO. 2

CONTROL OF BROWN-SPOT NEEDLE BLIGHT ON LONGLEAF PINE SEEDLINGS BY BENLATE FUNGICIDE-DIP TREATMENT

This study demonstrates the effects of benomyl root-dip treatment and PT ectomycorrhizae on the survival, growth, and brown-spot-infection on outplanted longleaf pine seedlings.

LOCATION: Study plot is located in eastern portion of compartment #155, Escambia Experimental Forest Site is about 1.2 mi. west of headquarters of the experimental forest.

CONTACTS: Escambia Experimental Forest, U.S. Forest Service, Rt. 3, Box 197B, Brewton, AL 36426 Tel. (205) 867-3942.

RWU 4503, Southern Forest Expt. Sta., U.S. Forest Service, 1925 34th St., Gulfport, MS 39501.

OBJECTIVE: To determine: (1) efficacy of benomyl root-dip treatment for brown-spot needle blight control over a wide geographic area, (2) optimal rate of benomyl, (3) duration of effective control, and (4) if longleaf pine survival and growth can be improved by utilization of Pisolithus tinctorius ectomycorrhizae.

DESIGN: Test consisted of 8 treatments X 4 sites X 5 blocks X 25 seedlings for a total of 4000 seedlings.

PLANTING: Seedlings were machine-planted in January 1982. Seedlings were planted 3-ft. apart in rows spaced at 10-ft. intervals. Blocks were separated by a 20 ft. buffer zone.

TREATMENTS:

A. Seedlings with Pt were treated with a 5% benomyl dip.
B. Seedlings with Pt were treated with a 10% benomyl dip.
C. Seedlings with Pt were treated with a 20% benomyl dip.
D. Seedlings with Pt were treated with clay (no benomyl).
E. Pt-free seedlings were treated with a 5% benomyl dip.
F. Pt-free seedlings were treated with a 10% benomyl dip.
G. Pt-free seedlings were treated with a 20% benomyl dip.
H. Pt-free seedlings were treated with clay (no benomyl).

RESULTS

Plant responses after four years in the field (December 1985)

Treatments	Survival %	Infection %	Stem Length (cm)	Stem Diam. (mm)	Height Growth %
Seedlings + Pt					
A. 5% benomyl	77.4	60.2	33.0	28.1	64.4
B. 10% benomyl	79.1	53.6	28.2	26.2	55.9
C. 20% benomyl	69.6	47.7	28.3	29.1	62.5
D. No benomyl	39.1	89.5	5.5	12.6	4.7
Mean	66.3	62.8	23.8	24.0	46.9
Seedlings - Pt					
E. 5% benomyl	57.4	58.0	21.2	24.2	41.8
F. 10% benomyl	73.9	55.7	29.0	24.5	60.1
G. 20% benomyl	66.1	48.0	40.0	28.7	72.9
H. No benomyl	33.9	90.3	6.0	14.0	6.9
Mean	57.8	63.0	24.1	22.9	45.4

SUMMARY

A 5% benomyl-clay root-dip treatment proved to be optimal for disease control and for stiumulation of growth of longleaf pine over a wide geographic area. Treatment effectively controlled disease for a 3-year period. Longleaf pine seedlings inoculated with PT ectomycorrhizae generally had significantly higher rates of survival and greater growth than their noninoculated counterparts.

ALABAMA TOUR - STOP NO. 3

GROWTH AND DISEASE RESPONSES OF A LONGLEAF PINE HYBRID

This study demonstrates the effect of a benomyl root dip treatment on the growth and brown-spot infection on a longleaf pine hybrid.

LOCATION: Study plot is located in eastern portion of commpartment #155 on Escambia Experimental Forest. Site is adjacent to Stop 2 approximately 1.2 mi. west of headquarters of experimental forest.

CONTACT: Escambia Experimental Forest, U.S. Forest Service, Rt. 3, Box 197B, Brewton, AL 36426 Tel. (205) 867-3942.

RWU 4503, Southern Forest Expt. Stqa., U.S. Forest Service, 1925 34th St., Gulfport, MS 39501. Tel. (601) 864-8256.

OBJECTIVE: To evaluate growth and brown-spot infection on a longleaf pine hybrid treated with a benomyl root-dip treatment.

DESIGN: Randomized Complete Block: Hybrid longleaf pine (1/4 loblolly X 3/4 longleaf) X 2 root dip treatments X 2 sites X 3 blocks X 10 seedlings = 120 seedlings.

PLANTING: Nursery-lifted seedlings were machine-planted in January 1982. Seedlings were planted at 3-ft. intervals and rows were spaced at 10-ft. intervals.

TREATMENTS:

PROGENY	DIP	SITES
1/4 lob X 3/4 longleaf	A. Benomyl/clay	2. Florida
	B. Clay	1. Alabama

RESULTS

HYBRID RESPONSES AFTER 4 YEARS IN FIELD (NOV. 1985)

Treatment	Survial %	Infection %	Stem Length cm	Diam. mm	Height Growth %
Alabama					
A. + Benomyl	87.8	19.8	138.8	44.5	100.0
B. - Benomyl	43.3	84.2	34.5	17.6	100.0
Florida					
A. + Benomyl	86.78	17.1	148.6	45.7	100.0
B. - Benomyl	30.0	84.9	62.3	22.6	100.0

SUMMARY

A benomyl root-dip treatment significantly improved tree survival and growth and reduced brown-spot infection on a longleaf/loblolly pine hybrid planted on sites in Alabama and Florida.

ALABAMA TOURS - STOP NO. 4

ESCAMBIA FARM FORTY

Forty acres of understocked second-growth longleaf pine forests were set aside in 1947 as a demonstration of small woodlot management. The goal was to produce high quality poles and logs on a 60-year rotation using low-cost natural regeneration methods that include patch shelterwood and group selection.

LOCATION: Study plot is located in compartment #156 of the Escambia Experimental Forest. Site is approximately 1.4 mi. west of headquarters of the experimental forest.

CONTACT: Escambia Experimental Forest. U.S. Forest Service, Rt. 3, Box 197B, Brewton, AL 36426 Tel. (205) 867-3942.

RWU-4105, Southern Forest Expt. Sta., U.S. Forest Service, Devall St., Auburn Univ., Auburn, AL 36849 Tel. (205) 826-8700.

RESULTS (40 years)

	Total Stand/A (> 3.5" d.b.h.)	Sawtimber stand/Acre (>9.5" d.b.h.)	
	Cu Ft	Cu Ft	Bd. Ft. (Int. 1/4")
Inventory 1947	846	508	3559
Inventory 1987	1392	1003	6417
Increase 1947-87	546	495	2858
Cut 1947-87	949	710	4370
Growth 1947-87	1495	1205	7228

SUMMARY

As of 1987 over half (22 acres) of the "40" have been harvested and naturally regenerated to longleaf pine, and now supports stands ranging in size from grass-stage seedlings to small poles. Nearly all the 1987 sawtimber volume of 6417 b.f./acre was located on 18 acres not yet regenerated, so that average acre with sawtimber trees carries about 14 m.b.f. Hardwoods, mostly in the slash-hardwood bottom average 330 cubic ft./acre, 58 percent in 10" d.b.h. class or larger. Management costs for the "40" averaged about $6 cash plus 12 man-hours of time annually over first 19 years, confined mostly to prescribed burning, marking trees for cut, and some control of cull hardwoods. The "40" has been prescribed burned ten times in 40 years for brush control, hazard reduction, and seedbed preparation.

GROWTH AND YIELD

Longleaf pine stands are generally slow starters, but once they reach sapling size, well-stocked stands compare favorably with other southern pines and may outgrow them on some sites. The average site index for natural longleaf stands is about 70 feet at index age 50 years. For more detailed growth and yield information and examples of utility, see the publications by Lohrey, Lohrey and Bailey, and Farrar in the Suggested Reading list.

Planted Stands

This information is based on thinned and unthinned plantations in the West Gulf area. These plantations originated on unprepared planting sites that were largely free of competing woody vegetation.

In unthinned plantations on site index 45 (index age = 25 years), the number of trees declines with age due to mortality, while basal area and volume increase due to diameter and height growth of surviving stems. Yields are highest for the oldest age and highest initial density. Yields are low at age 20, but more than double by age 30 and nearly double again by age 40.

Periodic and mean annual increment (PAI and MAI) both increase with age and initial density. PAI is highest between age 35 and 40 and MAI is highest at age 40. The PAI varies from about 0.7 cord per acre per year between ages 15 and 30 for 100 initial trees per acre, to about 3 cords between ages 35 and 40 for 600 trees per acre. The yields at age 40 vary from about 22 cords at the lowest initial density up to about 63 cords for the highest. The MAI would be about 0.6 and 1.6 cords per acre per year, respectively.

Data for thinned plantations, also taken from West Gulf stands, show excellent annual board-foot growth after about age 30 for site index 45. Board-foot growth increases as stand age and residual density increase and, in each case, board-foot growth is highest between ages 40 and 45. For all residual densities, the growth rate exceeds 500 board feet (Int. 1/4-inch rule) per acre per year beyond about age 30.

Cubic-foot growth increases with density, but decreases with age. It is always highest between ages 20 and 25. This growth rate varies from a low of about 0.6 cord per acre per year between ages 40 and 45 for 20 square feet to about 2.5 cords between ages 20 and 25 for 120 square feet. The cubic-foot volumes for thinned plantations and unthinned plantations under similar conditions of age, site index, and basal area are nearly equal.

Thinned Even-aged Natural Stands

Information on thinned natural stands of longleaf comes from the East Gulf area. Generally, thinned natural stands have somewhat more predicted cubic-foot volume than thinned plantations for comparable conditions of age, site index, and density, particularly after age 20. The reverse is indicated when considering board-foot volumes--the natural stands lag behind the plantations. Probably, the major reason is that plantations usually have fewer initial trees per acre and less hardwood competition than natural stands. This results in more rapid diameter growth and earlier development of sawtimber volumes. Natural stands tend to have higher initial densities and more competition, resulting in slower

diameter growth and later development of sawtimber volumes. This suggests that natural stands will require longer rotations than planted stands to obtain comparable sawtimber volumes, unless non-commercial thinnings are imposed to enhance early sawtimber production.

Periodic annual increment (PAI) in board feet for thinned natural stands on tite index 70 (index age = 50 years)[1] increases with age and tends to be greatest at low residual densities at early ages and greatest at high densities at older ages. Board-foot growth peaks between ages 40 and 50 for lower basal areas (40 or less square feet), but is greatest between ages 50 and 60 for the higher basal areas. Board-foot PAI exceeds 500 fbm only beyond age 40 and for residual basal areas of 60 square feet or greater. As in thinned plantations, cubic-foot growth increases with residual density and is greatest between ages 20 and 25 in all cases shown. It varies from about 0.6 cord per acre per year between ages 50 and 60 for 20 residual square feet to about 3.0 cords between ages 20 and 30 for 120 square feet.

[1]Corresponding site index for index age 25 is 45 feet.

ALABAMA TOUR - STOP NO. 5

REGIONAL LONGLEAF GROWTH STUDY

This plot represents one of some 280 permanent plots in a cooperative Midsouth study of managed natural longleaf pine growth and yield. The study covers a broad array of stand ages, site indices, and residual densities, maintained by periodic thinning. The study was started in the mid-1960s and has been remeasured every 5 years since. At each remeasurement the stands are rethinned, as needed, to maintain their assigned residual density levels and some new plots are added to replace those accidentally lost or to fill gaps in the distribution of plots. The intent is to maintain the study until 3 sets of the initially youngest plots have been managed for an entire rotation of perhaps 80 years. Such a long-term study is necessary to determine the quantity and quality of products produced over time under management, particularly sawlogs, veneer bolts, and poles.

The study has thus far produced considerable useful information and the utility improves with time as more of the stands have been under management for longer periods. The information produced includes site-index curves, tree-volume functions, stand volume and growth predictors, and computer simulation programs for estimating growth and yield under management.

In the fall of 1987, this particular plot was 36 years old, had a site index of 75 feet, and contained 111 square feet of total basal area, of which about 4 sq. ft. were in sawtimber. Assume that this plot represents a larger stand that we want to thin now from below to leave 80 sq. ft. of basal area, cut no sawtimber, and want estimates of the volume removed in thinning and the volumes 5 years from now or at age 41. The following tabulation shows this scenario and is generated from a microcomputer program that uses the stand volume and growth predictors developed from this study.

			STAND VALUES (per acre)						P.A.I.			
SI(50)	AGE	STATUS	BT	TotCF	MerCd	BS	SawCD	Int.1/4	TotCF	Mercd	SawCd	Int.1/4
75	36	b-c	111.00	2799.81	33.85	4.02	1.11	519				
		a-c	80.00	2033.19	24.72	4.02	1.11	519				
		Cut	31.00	766.62	9.24	.00	.00	0				
75	41	b-c	96.53	2630.75	32.26	10.15	3.08	1479	119.51	1.51	.39	192
		a-c	80.00	2189.80	26.88	10.15	3.08	1479				
		Cut	16.53	440.96	5.37	.00	.00	0				

We see in the tabulation that we initially had only about 520 board feet of sawtimber, which will not allow an operable sawtimber removal, so we do not simulate a sawtimber cut but make all our removal in pulpwood. The estimated cut is about 9.3 merchantable cords per acre and the estimated residual stand contains about 24.7 merch. cords. Note that the sawtimber basal area (BS) is part of the total basal area (BT) and, likewise, the cords in sawtimber (SawCd) are part of the merchantable cords (MerCd) so the pulpwood left at age 36 would be 24.7 - 1.1 = 23.6 cords. Five years later, at age 41, we estimate that our residual stand will have grown to have nearly 32.3 merch. cords containing nearly 3.1 sawtimber cords or 1480 bd. ft. As shown, we could again thin from below to leave 80 sq. ft. and cut an estimated 5.4 merch. cords. Again, although our sawtimber stand has grown from about 500 to nearly 1500 bd. ft., we defer any sawtimber cutting until a later age when we can make an operable cut (say, 1200 bd. ft.) and leave a desired stand for future growth.

On the right side of the tabulation are given the periodic annual increments (P.A.I.) from age 36 to age 41. We see that the estimated P.A.I.s were about 1.5 cords/ac./year in the merchantable stand and about 190 fbm/ac./year in the sawtimber stand.

This is just one of many simulations that might be performed to help a forest manager decide what thinning scheme he might employ on various sites for various management objectives. The simulatin could be extended to cover a rotation and various rotation lengths as well as thinning schemes could be compared. The forest manager could then use this information to help decide which would likely be his best option.

The legend for the tabulation is:

BT = total basal area, sq. ft., all trees $\geq$ 1" dbh.
TotCF = total cubic-foot volume, i.b., all trees $\geq$ 1" dbh.
MerCd = merchantable cords, trees $\geq$ 4" dbh to a 3" top dob.
BS = sawtimber basal area, sq. ft., trees $\geq$ 10" dbh.
SawCD = cords in sawtimber, trees $\geq$ 10" dbh.
Int.1/4 = board-foot volume, International 1/4" rule, trees $\geq$ 10" dbh.
P.A.I. = periodic annual increment.
b-c = before cut.
a-c = after cut.

ALABAMA TOUR - STOP NO. 6

LONGLEAF PINE SHELTERWOOD STAND

This plot demonstrates the natural establishment of longleaf pine by the Shelterwood System.

LOCATION: Stand is located in compartments #85, 95, and 105 of the Escambia Experimental Forest. Site is approximately 0.9 mi. west of headquarters on the experimental forest.

CONTACT: Escambia Experimental Forest, U.S. Forest Service, Rt. 3, Box 197B, Brewton, AL 36426 Tel. (205) 867-3942.

RWU-4105, Southern Forest Expt. Sta., U.S. Forest Service, Devall St., Auburn Univ., Auburn, AL 36849 Tel. (205) 826-8700.

SIZE OF UNIT: 80 acres in compartments 85, 95, and 105.

PREPARATORY CUT: January 1981; cut made to maximum of 60 sq. ft. basal area/acre. Average was less.

SEED CUT: November 1985; cut made to maximum of 30 sq. ft. basal area/acre leaving the best dominate trees.

CULTURAL TREATMENTS: Large hardwoods injected with herbicides May-June 1981. Open FOR FUEL-WOOD CUTTING, 1981. Prescribe-burned for competition control July 1981, August 1982, November 1984. August 1987 prescribed burned for seedbed preparation after cone inventory in the spring of 1987 indicated a good cone crop was in place. Stocking 1/88: Seedlings/acre (1987 cone crop) = 14,500; 98% of sampled milacres stocked with seedlings.

SUMMARY

The Shelterwood System is very effective, inexpensive approach for the natural regeneraton of longleaf pine.

ALABAMA TOUR - STOP NO. 7

NATURAL REGENERATION - SHELTERWOOD SYSTEM

This 80 acre stand was the first attempt to regenerate longleaf pine by a natural system on the Escambia Experimental Forest. From the observations in this stand, much was learned and research was initiated that eventually lead to the development of the Shelterwood System.

LOCATION: Study plot is located in compartments #93 and 94 of the Escambia Experimental Forest . Site is approximately 0.9 mi. west of headquarters of the experimental forest.

CONTACT: Escambia Experimental Forest, U.S. Forest Service, Rt. 3, Box 197B, Brewton, AL 36426 Tel. (205) 867-3942.

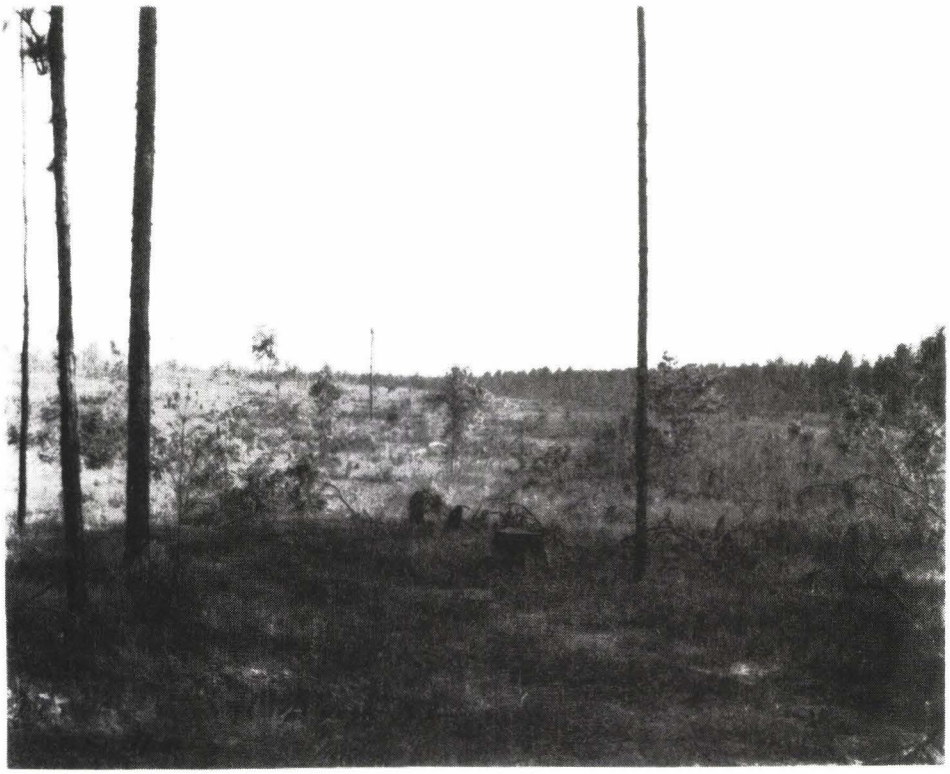
RWU 4105 Southern Forest Expt. Sta., U.S. Forest Service, Devall St., Auburn Univ., Auburn, AL 36849 Tel. (205) 826-8700.

SIZE OF UNIT: 80 acres in compartments 93 and 94.

STAND HISTORY: Seed crop - fall 1947. Seedlings established under full stand. Overstory cut winter of 1948-49 to 10 residual seed trees/acre Seed trees cut winter 1953-54, grass-stage seedling stand released. The stand has received no management since the removal cut except for prescribed burning on a three year cycle. The unmanaged condition has been maintained for research purposes.

SUMMARY

An accidental, modified, two-cut shelterwood resulted in establishment of longleaf regeneration. This "accident" provided the incentive for further research, development, and application of this natural regeneration system for longleaf pine.



A 1954 view of compartment 94 (stop #7) at the time of the removal cut. Advance reproduction is hidden in the grass

A 1962 view of compartment 94 (stop #7) 8 years after removal of seed trees and 1 year after a release treatment

ALABAMA TOUR - STOP NO. 8

SEASON OF BURN AND OVERSTORY DENSITY: EFFECT ON UNDERSTORY DEVELOPMENT

This study demonstrates the effect of biennial fire treatments on the development and growth of forest understories with a range of various overstory densities.

LOCATION: Study plot is in compartment 82 of Escambis Experimental Forest Site is approximately 1.5 mi. west of the headquarters of the experimental forest.

CONTACT: Escambia Experimental Forest, U.S. Forest Service, Rt. 3, Box 197B, Brewton, AL 36426 Tel. (205) 867-3942

RWU 4105 Southern Forest Expt. Sta., U.S. Forest Service, Devall St., Auburn Univ., Auburn, AL 36849 Tel. (205) 826-8700.

DESIGN: Study compares four fire treatments (biennial burns in winter, spring, summer, plus unburned check) under each of four initial densities (20, 30, 40, and 50 sq. ft. basal area/acre) of overstory pine. Total of 16 treatment combinations in each of two locations. All hardwoods controlled before study establishment. No hardwood control treatments except by fire since establishment.

STAND HISTORY: Initial burns in 1970, with 9th burning cycle in 1986, and completed with burn in winter of 1986-87.

BLOCK LAYOUT AND IDENTIFICATION

	Summer B	Spring* C	No burn D	Spring C	Spring*
	Winter A	No burn D	Summer B	Winter A	Winter
Initial Density (basal area/acre)	20 ft^2		50 ft^2		30 ft^2

RESULTS

After 10 years (1980) treatments had affected development of understory pine and hardwood. Number of stems per acre (more than 1.5" d.b.h. for the 16 treatments are tabulated below.

Overstory Density ($Ft.^2$ BA)	Longleaf Pine In-Growth 2" to 6" d.b.h. class					All Hardwoods 2" d.b.h. Class and Up				
	Winter Burn (A)	Spring Burn (C)	Summer Burn (B)	No Burn (D)	Avg.	Winter Burn (A)	Spring Burn (C)	Summer Burn (B)	No Burn (D)	Avg.
20	133	208	239	279	215	18	2	14	181	54
30	21	42	24	105	48	16	1	6	112	34
40	2	31	9	147	47	4	0	0	116	30
50	6	6	6	15	8	6	2	10	92	28
Average	40	72	70	136	80	11	1	8	125	36

Treatments for the 20 and 50 sq.ft. BA/acre overstories have been signed on the ground as follows: A - Winter burn, B - Summer burn, C - Spring burn, D - no burn.

SUMMARY

1. Season of burn does not have a great effect on longleaf seedling development which was actually somewhat better with growing season than dormant season burns.

2. Hardwood development inhibited by burning, and virtually non-existent with spring burns.

3. Development of both pine and hardwood inhibited by increasing overstory density. Longleaf pine development restricted under overstory densities above 20 sq. ft., particularly when burned.

4. Appears that, under low understory densities, periodic spring burns result in best combination of maximum development of pine regeneration with minimum hardwood encroachment.

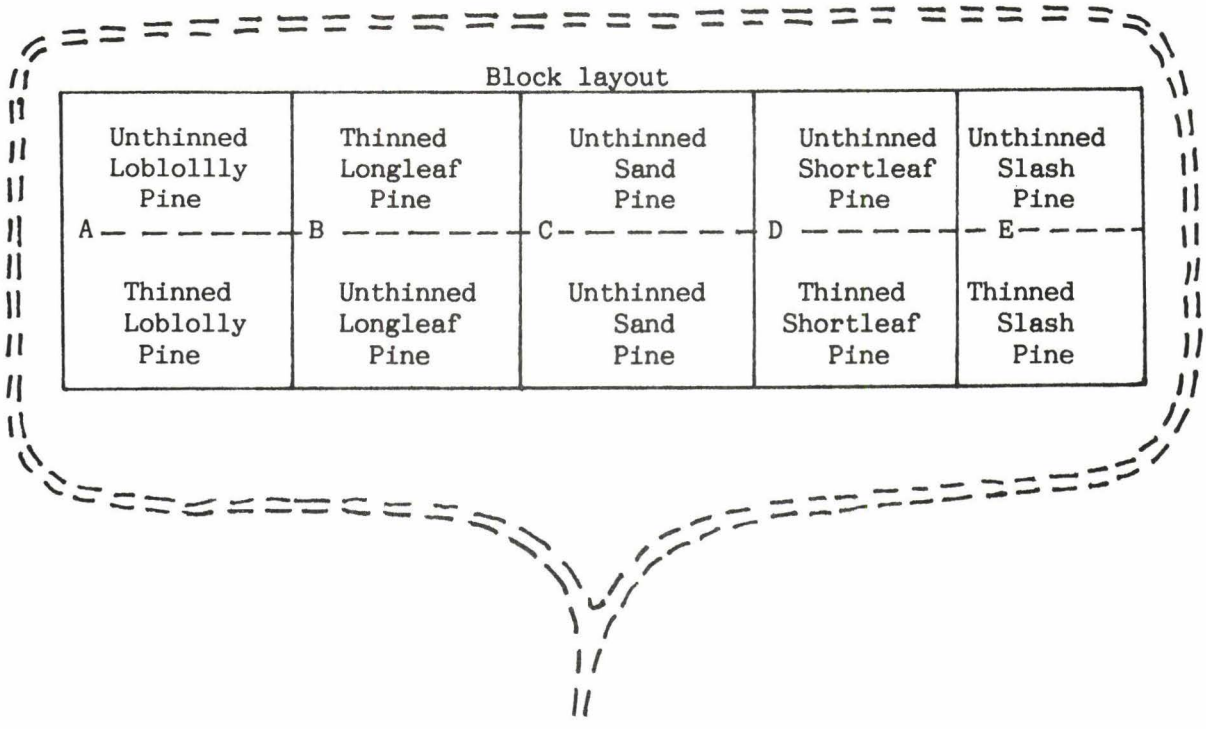
ALABAMA - STOP NO. 9

PEST RESISTANCE OF LONGLEAF PINE

In the winter of 1956-57, 1-acre plots of five different pine species were direct seeded on an abandoned old field that was disked in the late summer before the winter seeding. Seed were broadcast sown using local seed sources for loblolly pine, longleaf pine, sand pine, shortleaf pine, and slash pine. In the winter of 1959-60 one-half of the slash, loblolly, and shortleaf pine blocks were hand thinned to a 8 x 8 foot spacing. One-half of the longleaf pine block was thinned to 8 x 8 feet in 1962. The sand pine block was not thinned (see block layout sketch).

The original study has been closed but the study plots were retained for demonstrations, growth measurements and observations of disease and insects outbreaks.

As you walk through this demonstration observe the impacts that various pest are having on each species. Each block is identified with a letter on a post as you enter. Trail is marked with aluminum paint. A - Loblolly pine, B - Longleaf pine. The impacts can be seen by the gaps in the crown canopy, amount of dead trees standing and on the ground, and occurence of stem cankers on live trees.



Observations made in October 1987 when the demonstration was initiated included:

Block	Species	Observation
A	Loblolly pine	Ips beetles hae taken heavy toll especially in the unthinned portion. A moderate amount of stem cankers are present.
B	Longleaf pine	Light occurence of stem cankers - little evidence of mortality.
C	Sand pine	This is not a normal sand pine site. Mortality was heavy due to a root rot.
D	Shortleaf pine	Light mortality due to supression - not pests.
E	Slash pine	Fusiform rust has taken a heavy toll especially in the thinned block. Many stem cankers are still present in standing trees. Losses due to insects appear to be present but light.

CONCLUSIONS

Pests can cause heavy losses, especially on high risk sites. Forest managers should consider a wide range of factors when selecting a pine species for reforestation purposes--the least of which is not potential pest losses.

ALABAMA TOUR - STOP NO. 10

MANAGING FOR POLE PRODUCTION

Longleaf pine generally produces a higher percentage of poles than other southern pines. Poles generally bring 30-40 percent higher stumpage prices than if sold for sawtimber. In this one acre plot, the pole quality stems are marked with blue paint and all other merchantable stems are unmarked. Plot boundary marked with aluminum paint, with a stake at each corner.

In 1987 a measurement of this plot provided this data:

	Poles	Non-poles
Trees per acre 8" DBH +	50	78
Cubic feet of merchantable wood on trees 8" DBH +	1108(41%)	1624(59%)

Assuming sawtimber stumpage is $150/MBF and pole stumpage is $225/MBF, the per acre timber value would be--

-- $ 2957 if sold and merchandized into sawlogs and poles.

-- $ 2460 if sold and merchandized only as sawlogs.

If poles are an objective of stand management, thinnings should be lighter than usual with concentration on leaving the best pole candidates and less on spacing and density.

ALABAMA TOUR - STOP NO. 11

PREPARING FOR NATURAL REGENERATION

This stand demonstrates the initial stage of regenerating longleaf pine on using the Shelterwood System.

LOCATION: Stand is in compartments #41 and 42 of the Escambia Experimental Forest. Site location is approximately 3.0 mi. west of the headquarters of the experimental forest.

CONTACT: Escambia Experimental Forest, U.S. Forest Service, Rt. 3, Box 197B, Brewton, AL 36426 Tel. (205) 867-3942.

RWU 4105, Southern Forest Expt. Sta., U.S. Forest Service, Devall St., Auburn Univ., AL 36849 Tel. (205) 826-8700.

SIZE OF UNIT: 100 acres in compartments 41 and 42.

PREPARATORY CUT: June 1984, cut to maximum 70 sq. ft. basal area/acre leaving the best dominants and codominants.

CULTURAL HISTORY: Open for firewood cutting 1983-1984.
Prescribe burned winter of 1978, 1981, 1984, and 1987.

SUMMARY

With good forest management over a rotation, a preparatory cut will not be necessary since periodic thinning will maintain stand densities of 70-80 ft.^{2} basal area on medium sites. This stand will be regenerated in accordance with the Experimental Forest management plan. If this last thinning in 1984 represents the preparatory cut in a 3-cut shelter wood system, the sequence would call for a seed cut in 1989 and a final removal cut in 1994, given an adequate stand of established seedlings one or more years old.

ALABAMA TOUR - STOP NO. 12

MANAGEMENT OPTIONS FOR DENSE SEEDLING/SAPLING STANDS

CAUTION: Research measurement plots are adjacent to this demonstration stop. If you choose to visit the plots, feel free to do so but, please "walk lightly" so as not to alter any stand or stem measurements.

Naturally regenerated stands normally have more stems than necessary to be adequately stocked. Research has shown that diameter growth on crop stems can be increased by precommercially thinning to remove surplus stems. This treatment, when properly applied, will shorten (1) the time needed to reach merchantable size, and (2) the rotation. However, a prudent land manager should weigh these gains against the cost and expected return before initiating the treatment.

The decision to precommercially thin is not easy because of the many variables that must be considered in the analysis process. The nature of longleaf pine makes the decision easier than with other southern pines. Longleaf pine naturally begins establishing crown class positions even in the seedling and sapling sizes by its height growth paterns. For example, look at this 1/100 acre plot. Measurements taken in the fall of 1987 provided this data:

1. 3800 trees per acre (including seedlings)
2. 600 dominants and co-dominants per acre
3. 4.0" average diameter at breast height ranging from 3.4 to 4.5 for the 600 D&C
4. From seed the stand was 20 years old in fall of 1987

Dominants and co-dominants are identified by an aluminum band and all other stems on the plot with a blue band.

In this situation precommercial thinning would probably not be cost effective because:

1. Already 600 trees per acre have established dominance and will likely retain that position without the treatment. At this point, removing all stems other than the 600 dominants/co-dominants will not appreciably increase the growth of the stand.
2. If mechanical means are used (such as a rolling drum chopper) some of the 600 will be inadvertently lost and some of the others will be retained. (Estimated cost of this treatment in 1987 was $30-40/acre).
3. If hand tools were used, the cost would be very expensive ($60-80 per acre using 1987 prices).

As a rule-of-thumb, precommercial thinning should be considered in longleaf seedling/sapling stands when dominant/co-dominant count exceeds 1,500 per acre.

PLANTING BARE-ROOT LONGLEAF PINE SEEDLINGS

Research and experience has led us to conclude that there are five very distinct phases that are inter-dependent to have successful planting with longleaf pine. These five phases or keys are: (1) well prepared, competition-free sites, (2) healthy, top quality, fresh planting stock, (3) meticulous care and handling of the stock from lifting to planting, (4) proper planting procedures, and (5) timely post-planting care.

These basic components must be viewed as the proverbial chain which is no stronger than its weakest link. If longleaf pine managers miss the mark on any one of these components, the results will likely be disappointing. There are few compensations to make in one component to offset inadequacy in another component. For example, no amount of intense site preparation will be adequate to overcome the disappointing results from using poor planting stock. Conversely, inadequate site preparation cannot be compensated for by using only the very best planting stock.

Longleaf pine seedlings do not initiate height growth until the root collar diameter (RCD) reaches 1-inch. The period of time the seedling takes to reach that 1-inch thus hold is commonly known as the grass stage. Managers must strive to get seedlings to 1-inch RCD within the first growing season. It can be done and should be if success is to be consistent. Here's how it can be done.

Site Selection

Longleaf pine will grow on a wide variety of sites ranging from deep sands to moderately wet soils. It will grow on loamy, clayey, silty, and sandy soils. Within its range, the major site restrictions to establishing longleaf pine are flooding and competition from other vegetation. Normally the wetter a site, the more vigorous the naturally occurring competing vegetation. Because longleaf pine is so intolerant of competition vegetation, it must be controlled on all sites until the pine seedlings are well ahead. On the wetter sites this is more difficult because of the more aggressive nature of the competition. If for any reason (economics, lack of equipment, etc.) the manager cannot control the competing vegetation during the establishment stage, then the site should not be reforested with longleaf pine. The site for reasons other than soils is simply not a longleaf site.

Fire generally plays an important role in the establishment and management of longleaf pine stands. A good rule-of-thumb is to avoid putting longleaf pine on sites that are normally too wet in the winter months to carry a fairly hot prescribed fire. By the same reasoning, longleaf pine can be established on any site that will carry such a fire, providing the other establishing requirements are met. We need to dispel the notion that longleaf pine should only be grown on the dry, infertile sites. That policy unnecessarily restricts forest managers by eliminating a management option that, when all things are considered (e.g. fire occurrance, markets, possible pest losses, economics, etc.), may be the best on many sites.

Site Preparation

The primary purposes of site preparation should be to control the competition and create conditions conducive to effective planting. Most common methods of site preparation use mechanical equipment, chemical herbicides, prescribed fire, or some combinations of these. Prescriptions for competition control must be site-specific. Intensity of site preparation depends on type and severity of competition on the site. Avoid inappropriate methods, such as intensive mechanical site preparation on fragile upland sites.

Competition control must be complete enough that planted seedlings will be in height growth before (1) brown-spot disease problems develop and (2) the competition returns to a level detrimental to seedling growth. The greater the reduction in competition, the more rapid the growth of planted longleaf pine seedlings. The time of height-growth initiation and rate of early seedling height growth is dependent on severity of competition, and is relatively independent of site quality.

Since longleaf pine seedlings are best planted with machines, the site should be clean enough to facilitate efficient movement of the tractors and machines over the planting site. Soil disturbing treatments such as discing or drum chopping should be completed far enough in advance of scheduled machine planting that soils have settled down and firmed up by subsequent rains.

Residual seedlings of natural seeding origin that remain after the clearcut should be eliminated during the site preparation operations if brown-spot disease occurs in the area. They are a source of inoculum that threatens the planted seedlings.

Many successful longleaf pine managers program a series of prescribed fires as much as ten years in advance of clearcuts to clear the understory of competing vegetaton. This often allows the intensity of the site preparation treatments to be reduced.

Quality of Planting Stock

The quality of seedlings is as important as any other factor in the success (or failure) of longleaf pine plantings. Generally, acceptable longleaf seedlings will cost more than other southern pines primarily because of higher seed cost and lower seedling density in the nursery beds. Ideally, bare-root seedlings should have (1) a root collar diameter 0.4-inch or larger, (2) numerous 8 to 10-inch lateral roots with evidence of ectomycorrhizal development, (3) a stout tap root 8 to 10-inches long, (4) a winter bud with scales, (5) abundant, largely-fascicled needles that are disease free, (6) been lifted from the nursery bed no more than 10 days prior to planting, and (7) been in a full state of winter dormancy when lifted from the nursery beds.

In addition seedlings to be planted in areas where brown-spot needle disease is known to exist should have their roots treated at the nursery with the systemic fungicide, benomyl. This simple and inexpensive treatment can make the difference betyween a successful and failed plantation.

Many plantations fail because cull seedlings are planted as in this 1953 plantation. Top quality seedlings are essential for successful plantations.

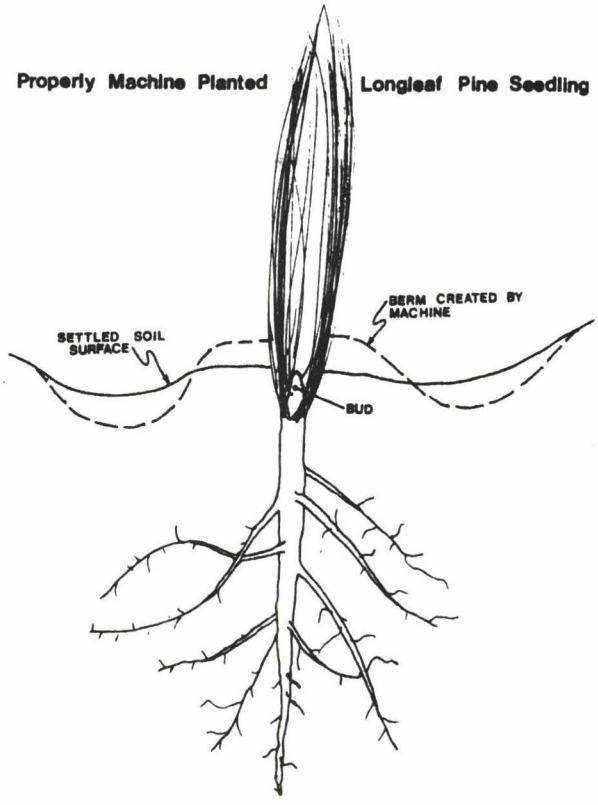
Seedling Care and Handling

Generally, this is the area that definitive answers are least available - we don't know the scale of consequences for poorly handling and caring for longleaf pine seedlings. There is evidence that they are more sensitive to desiccation, chemical damage, and mechanical damage than other southern pine seedlings. For this reason, it is proper that meticulous be the adjective most descriptive of our care and handling practices. Highly desirable practices include: (1) allowing no field root-pruning (modify the planting hole to accommodate the best possible root system rather than the roots to fit an inadequate hole), (2) pre-chill seedlings 48 hours at the nursery before shipping (3) ship and store seedlings in refrigerated equipment where temperatures are maintained at 33-45 degrees F., (4) plant all seedlings within 10 days of lifting from the nursery bed, (5) use bags rather than bales and keep bags air tight (repair tears and reseal tightly after opening), (6) remove from cold storage only the trees that will be planted each day (7) keep bags shaded and the coolest possible temperature during transport to and storage at the planting site, and (8) keep root exposure to a minimum by protecting them from drying conditions after removal from the bag.

Planting Procedures

Longleaf pine bare-root seedlings ideally should be machine planted. Large root systems and proper root alignment can better be accommodated in the larger planting opening a machine creates. The speed of the tractor should be slowed so that careful and accurate placement of the seedlings can be made. Attempts to plant at the speed normally used for loblolly and slash pines will likely result in a high percentage of improperly planted seedlings.

Plant on soils that are firm and settled after site preparation treatments so that soil movement after planting will be minimized. This is desirable because of the very critical positioning of the longleaf pine seedlings terminal bud. Plant seedlings so that the terminal bud is at or slightly below (0.5-inch) the soil surface. One must take into account the possible soil movement onto or away from the seedling in the 2-3 months after planting. Normally on course textured soils more soil will move away from the planted seedlings micro-site than onto it. Seedlings with the root collars positioned above the soil surface are very poor risk.



Planted seedlings should be in a hole that was firmly closed from top to bottom. Other policies that have proven beneficial are (1) discard any seedling with a RCD less than 0.4-inch or that exhibits any other sign of deficiency (2) plant on the contour in order to not encourage erosion, and (3) initiate effective quality control measures to cover the entire planting program to insure that identification and correction of problems are taken before they become uncorrectable or have serious consequence.

Post-Planting Management

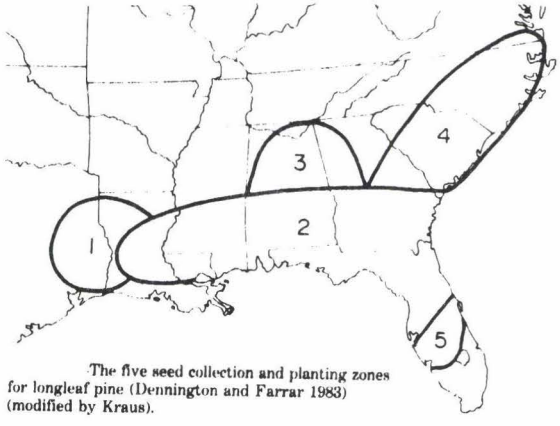
Until height growth is initiated, longleaf pine seedling stands should be checked at least annually to determine if (1) livestock grazing is adversely impacting the reforestation effort, (2) brown-spot disease infestation is prersent to a level where control measures are needed, (3) seedling survival is adequate and (4) competing vegetation is remaining in check. Corrective measures for each situation generally understood by most southern foresters. However 2 and 4 merit special comments.

While it is true, properly applied prescribed fire will control the disease, not all stands with infection should be burned. Before using fire, a survey of the stand should be made to determine the degree of infection and if seedlings are large enough to survive the fire. About 100 milacre plots are required to make a diagnosis for the stand, and examination should be confined to the best crop seedling on each plot. If 20-percent or more of all the cumulative foliage on the sampled crop seedlings is infected, a burn should be considered.

Timing is important. One study found that when 40-percent or more of the needle surface was infected, mortality from the fire exceeded survival. Data from the same study also suggested that seedlings are susceptible or resistant to mortality from fire according to four root collar size classes: (1) susceptible grass stage (less than 0.3-inch), (2) resistant grass stage (0.3 to 0.7-inch), (3) susceptible height-growth stage (0.8 to 1.4-inches) and resistant height-growth stage (1.5-inches and larger).

Some scientists have observed that a lower intensity of mechanical site preparation combined with a post-planting herbicide treatment appears more effective in promoting seedling height growth than a higher initial level of mechanical site preparation alone. Nevetheless, seedlings must have competition controlled until seedling height is above it irregardless of whether the control measures were applied before or after the planting.

Seedlings to be planted in one of the five seed collection and planting zone should originate from seed collected in the same zone. Moving seed/seedlings out out of their native zone may jeopardize the success of the planting efforts and effect future yields.



The five seed collection and planting zones for longleaf pine (Dennington and Farrar 1983) (modified by Kraus).

ALABAMA TOUR - STOP NO. 13

HOLLY FORK PLANTATION: T. R. MILLER

This plantation demonstrates successful longleaf pine regeneration by using proven site preparation and seedling-handling techniques. It also shows comparable growth responses of longleaf and slash pine on the same site.

LOCATION: Site location is approximately 6 mi. SE of the headquarters of the Escambia Experiemtnal Forest and 1.4 south of the Three Notch road.

CONTACT: Escambia Experimental Forest, U.S. Forest Service,Rt. 3, Box 197B, Brewton, AL 36426 Tel. (205) 867-3942.

RWU-4105, Southern Forest Expt. Sta., U.S. Forest, Devall St., Auburn Univ., AL 36849 Tel. (205) 826-8700.

Frank Jones, T. R. Miller Co., Brewton, AL Tel. (205) 867-6165.

STAND HISTORY: Site prepared with V blade, rake, and disk.

PLANTING: Seedlings were obtained from the Hauss Nursery at Atmore, AL. They were machine-planted in the winter of 1973-74.

TREATMENTS:
1. 950 acres of longleaf pine
2. 350 acres of slash pine (planted same time as longleaf)

RESULTS

Plantation established by machine planting on completely prepared sites--sheared, windrowed, burned, disced in winter 1973-74.

Age	Trees/acre	d.b.h. (in.)	Height (ft)		Basal area (ft^2) per acre	Volume (ft^3 i.b.)	
			Dom. Co-dom.	All		> 3.5"	Total
4	463	0.5	7	4	2	--	5
7	456	2.0	16	13	13	--	85
10	453	3.7	27	24	37	342	405
13	450	4.6	38	33	56	797	820

SUMMARY

With proper technology, longleaf pine on upland sites may produce as much growth as slash pine on the same sites with much lower risk of losses from fire and fusiform rust.

ALABAMA TOUR - STOP NO. 14

PARKER BRIDGE ROAD PLANTATION - T. R. MILLER

This plantation demonstrates successful longleaf pine regeneration on a very poor site (20-ft deep sand site) with the use of proven site preparation and seedling-handling techniques.

LOCATION: Plantation is located approximately 12 mi. from Brewton via Ridge road, #22, #29, and Parker Bridge road.

CONTACT: Escambia Experimental Forest, U.S. Forest Service, Rt. 3, Box 197B, Brewton, AL 36426 Tel. (205) 867-3942.

RWU-4105, Southern Forest Expt. Sta., U.S. Forest Service, Devall St., Auburn Univ., AL 36849 Tel. (205) 826-8700

Frank Jones, T. R. Miller Co., Brewton, AL., Tel. (205) 867-6165

STAND HISTORY: Site was prepared by V blade, rake, and disk. Seedlings were obtained from the Hauss Nursery at Atmore, AL. Longleaf is planted on lakeland soils.

PLANTING:
1) A total of 30 acres were machine-planted in the winter of 1980-81.
2) A total of 50 acres were machine-planted in the winter of 1981-82.

Stand data based on 1987 measurements

	Average for dominants	
TPA	DBH	Height
575	2.5"	16'

At the demonstration sign, note that loblolly is planted (to your left) on the wetter site where competition is more aggressive and difficult to control. Even so it is interesting to note that in 1987 the longleaf stems next to the loblolly were as tall.

SUMMARY

Longleaf pine can be successfully machine-planted on prepared deep sandy sites on an operational basis.

ALABAMA TOUR - STOP NO. 15

BEAR ISLAND PLANTATION - T. R. MILLER

This plantation demonstrates successful longleaf pine regeneration by using proven site preparation and seedling-handling techniques.

LOCATION: Stand location is approximately 13 mi. east of Brewton, on US 29 travel 1.2 miles NE past County road #22, turn right and travel another 1.2 miles on a dirt road.

CONTACT: Escambia Experimental Forest, U.S. Forest Service, Rt. 3, Box 197B, Brewton, AL 36426 Tel. (205) 867-3942

RWU-4105, Southern Forest Expt. Sta., U.S. Forest Service, Devall St., Auburn Univ., AL 36849 Tel. (205) 826-8700

Frank Jones, T. R. Miller Co., Brewton, AL., Tel. (205) 867-6165

STAND HISTORY: Site was prepared by V blade, rake, and disk. Seedlings were obtained from the Hauss Nursery at Atmore, AL.

PLANTING: A total of 100 acres were planted during the winter of 1978-79.

Stand data based on 1987 measurements

Average for dominants

TPA	DBH	Height
750	3.6	27'

SUMMARY

Longleaf pine can be successfully machine-planted on prepared sandy sites in the East Gulf Middle Coastal Plain on an operational basis.

ALABAMA TOUR - STOP NO. 16

SHADY GROVE PLANTATION - T. R. MILLER

This plantation demonstrates various types of site preparation for the successful regeneration of longleaf pine.

LOCATION: Plot location is approximately 10 mi. east of Brewton via Ridge road and #22. Site is on dirt road just past Shady Grove Church.

CONTACT: Escambia Experimental Forest, U.S. Forest Service, Rt. 3, Box 197B, Brewton, AL 36426 Tel. (205) 867-3942.

RWU-4105, Southern Foret Expt. Sta., U.S. Forest Service, Devall St., Auburn Univ., AL 36849 Tel. (205) 826-8700.

Frank Jones, T. R. Miller Co., Brewton, AL. Tel. (205) 867-6165.

STAND HISTORY: This stand was machine or hand-planted in the winter of 1970-1971. Seedling source was the Hauss Nursery at Atmore, AL. A total of 95 acres were planted.

TREATMENTS:

Site Preparation	Planting
1. V blade, rake	1. Hand-plant
2. V blade, rake, disk	2. Machine-plant
3. V blade, rake, bedding	

RESULTS

Plantations established by machine planting on completely prepared sites--sheared, windrowed, burned, disced in winter 1970-71.

Age	Trees/acre	d.b.h (in.)	Height (ft)		Basal area (ft^2) per acre	Vol ($ft.^3$ i.b.)	
			Dom. Co-dom.	All		>3,5"	Total
			SHADY GROVE (bedded)				
4	750	1.0	8	6	6	--	23
7	725	2.5	20	17	30	--	229
10	720	3.3	29	27	46	326	541
13	720	4.2	40	37	73	1069	1152
16	720	4.7	47	44	91	1626	1697
			SHADY GROVE (not bedded)				
4	890	0.4	6	4	3	--	10
7	827	2.0	17	13	24	--	172
10	823	2.9	26	22	44	264	471
13	790	3.9	35	32	73	949	1072
16	783	4.4	44	39	93	1574	1664

SUMMARY

The early growth of longleaf pine stands planted with improved techniques on well prepared sites are comparable to old-field plantations and superior to well-managed, naturally reproduced stands.

ALABAMA TOUR - STOP NO. 17.

BREWTON-DUMP PLANTATION - T. R. MILLER

This plantation demonstrates a combination of natural and machine-planted regeneration.

LOCATION: Plot location is approximately 4 mi. east of Brewton via Ridge road. Turn at Brewton Landfill sign. Site in across from current landfill site.

CONTACT: Escambia Experimental Forest, U.S. Forest Service, Rt. 3, Box 197B, Brewton, AL 36426 Tel. (205) 867-3942.

RWU-4105, Southern Forest Expt. St., U.S. Forest Service, Devall St., Auburn Univ., AL 36849 Tel. (205) 826-8700.

Frank Jones, T. R. Miller Co., Brewton, AL
Tel. (205) 867-6165.

STAND HISTORY: The site, originally the Brewton dump, was regenerated yearly as the dump site was discarded and covered. The site was regenerated from the winter of 1980-1981 onward. It has been planted by machine about 4 times within the 1980-1986 time frame. Site preparation was not needed. Seedlings planted by machine were obtained from the Hauss Nursery at Atmore, AL. Natural seedling has occurred yearly with varying degrees of success.

SUMMARY

With proper technology, longleaf pine stands planted on prepared sites can be comparable or even superior to successful natural regeneration.

ALABAMA TOUR - STOP NO. 18

VIRGIN STAND OF LONGLEAF PINE - HAUSS PARK

The stand represents a rare, old-growth stand of longleaf pine. Diameter has increased about 5 inches during the last 30 years. Ring samples indicated age to be about 180 years. Younger age classes have filled in under low-density parent stand. Absence of burning in recent years has permitted substantial hardwood encroachment in the understory.

LOCATION: This longleaf pine stand is located approximately 1 mi. east of Flomaton, AL on Highway 31.

CONTACT: Escambia Experimental Forest, U.S. Forest service, Rt. 3, Box 197B, Brewton, AL 36426 Tel. (205) 867-3942.

RWU-4105, Southern Forest Expt. Sta., U.S. Forest Service, Devall St., Auburn Univ., AL 36849 Tel. (205) 826-8700.

Suggested Reading

Baldwin, V. C., Jr. and J. R. Saucier 1983. Above ground weight and volume of unthinned, planted longleaf pine on West Gulf forest sites. U. S. Forest Serv., Research Paper SO-191, 25p.

Barnett, J. P. 2969 Long-term storage of longleaf pine seed. Tree Planters' Notes 20(2): 22-25p.

Barnett, J. P. and A. G. Kais. 1986. Longleaf pine seedling storability and resistance to brown-spot disease improved by adding benomyl to the packing medium.
In Proceedings: Fourth Biennial Southern Silviculture Research Conference. November 1986, GTR SE-42, SE For. Exp. Sta., Asheville, N.C. 598p.

Boyer, W. D. 1975. Timing overstory removal in longleaf pine forest. J. Forestry 73:578-580.

Boyer, W. D. 1977. Stocking percent and seedlings per acre in natural established longleaf pine. J. For. 75:500, 505-506.

Boyer, W. D. 2979. Regenerating the natural longleaf pine forest. J. Forestry 77:572-575.

Boyer, W. D. 2980. Interim site-index curves for longleaf pine plantations. U. S. Forest Serv. Res. Note SO-261, 5p.

Boyer, W. D. 1982. Growth of young longleaf pine as affected by biennial burns plus chemical or mechanical treatments for competition control. In proceedings: Second Biennial Southern Silviculture Research Conference, Nov. 1982, General Tech. Rept. SE-24. 1983.

Boyer, W. D. 1985. First-year survival of planted longleaf pine bare-root and container stock as affected by site preparation and release. In proceedings, Third Biennial Southern Silvicultural Research Conference, Nov. 1984. Gen.Tech. Rept. SO-127. 3p.

Cordell, C. E., A. G. Kais, J. P. Barnett and C. E. Affeltranger 1984. Effects of benomyl root storage treatments on longleaf pine seedling survival and brown-spot disease incidence. Proc. 1984 South. Nurs. Conf: 84-87.

Croker, T. C., Jr. 1967. Crop seedling method for planning brown-spot burns in longleaf pine. J. For. 65:488.

Croket, T. C., Jr. 1971. Binocular counts of longleaf pine strobili. U. S. Forest Serv. Res. Note SO-127. 3p.

Croker, T. C., Jr. 1987. Longleaf pine: A history of man and a forest. For. Rept. R8-FR7, USDA-For. Serv., Atlanta, GA, 37p.

Croker, T. C., Jr., and W. D. Boyer. 1975. Regenerating longleaf pine naturally. USDA For. Serv. Res. Pap. SO-105, 21p. Southern For. Exp. Sta. New Orleans, LA.

Dennington, R. W. and R. M. Farrar, Jr. 1983. Longleaf pine management. For. Rept. R-8 FR 3, 17p. U. S. Forest Service, Atlanta, GA.

Dorman, K. W. 1976. The genetics and breeding of southern pines. Agriculture Handbook No. 471, USDA Forest Service, Washington, D.C. 407p.

Farrar, R. M., Jr. 1985. Volume and growth predictions for thinned even-aged natural longleaf pine stands in the east Gulf area. Research Paper So-220. 171p. New Orleans, LA., USDA Forest Service. South. For. Exp. Sta.

Farrar, R. M., Jr. 1981. Cubic-foot volume, surface area, and merchantable height functions for longleaf pine trees. U. S. Forest Serv. Res. Paper SO-166, 7p.

Farrar, R. M., Jr. 1985. Predicting stand and stock tables from a spacing study in naturally regenerated longleaf pine. Research Paper SO-219. 28p. New Orleans, LA., USDA Forest Service. South. For. Exp. Sta.

Farrar, R. M., Jr., and White, J. B. 1982. Early development of longleaf pine planted on prepared sites in the East gulf. In proceedings: Second Biennial Southern Silviculture Research Conference, Nov. 1982, General Tech. Rept. SE-24.

Grelen, H. E. 1978. May burns stimulate growth of longleaf pine seedlings. U. S. Dept. Agric. For. Serv. Res. Note SO-234. 5p. South. For. Exp. Sta., New Orleans, LA.

Guldin, R. W. 1982. Container-grown longleaf pine regeneration costs in the sandhills. South. J. Appl. Forestry 6:33-39.

Hatchell, G. E. 1986. Nursery cultural practices, Seedling Morphology, and field performance of longleaf pine. In Proceedings: Fourth Biennial Southern Silviculture Research Conference. Nov. 1986, GTR SE-42, SE For. Exp. Sta., Asheville, N.C. 598p.

Henry, B. W., and Wells, O. O. 1967. Variation in brown-spot infection in longleaf pine from several geographic sources. U. S. Dept. Agric. For. Serv. Res. Notes SO-52, 4 p., South. For. Exp. Sta., New Orleans, LA.

Hu, S., and P. Y. Burns. 1986. Longleaf pine, a bibliography 1858-1984. Res. Rept. 6. LSU, Baton Rouge, LA., p 93.

Kais, A. G., and Margene M. Griggs. 1984. Control of Brown-Spot Needle Blight Infection on Longleaf Pine through benomyl treatment and breeding. In proceedings Recent Research on Conifer Needle Diseases, Oct. 1984, Gulfport, MS. Gen. Tech. Rept. WO-50. Washington, D.C. USDA - Forest Service, 1986. p. 15-19.

Kais, A. G., G. A. Snow, and D. H. Marx 1981. The effects of benomyl and Pisolithus tinctorium ectomycorrhizae on survival and growth of longleaf pine seedlings. S. J. Appl. For. 5(4): 189-195.

Lantz, C. W. and J. F. Kraus 1987. A guide to southern pine seed sources. USDA For. Ser. GTR SE-43, 34p. SE For. Exp. Sta., Asheville, NC.

Lohrey, R. E. 1978. Predicted growth of longleaf pine planted on cutover forest sites in the West Gulf. In Proceedings: Longleaf Pine Workshop, Oct. 1978, Mobile, AL., Tech. Pub. SA-TP3, Atlanta, GA: U. S. Dept. of Agri., Forest Service, p. 54-64.

Lohrey, R. E., and R. L. Bailey. 1977. Yield tables and stand structure for unthinned longleaf pine plantations in Louisiana and Texas. U. S. Dept. Agric. For. Exp. Sta., New Orleans, LA.

Mann, W. F., Jr. 1970. Direct seeding longleaf pine. USDA For. Serv. Res. Pap. SO-57.

Maple, W. R. 1976. How to estimate longleaf seedling mortality before control burns. J. Forestry 74: 517-518.

Maple, W. R. 1977. Planning longleaf pine regeneration cuttings for best seedling survival and growth. J. For. 75:25-27.

Maple, W. R. 197. Spring burn aids longleaf pine seedling height growth. U. S. Forest Serv. Res. Note SO-28, 2p.

Schmedlling, R. C. 1986. Relative performance of longleaf compared to loblolly and slash pines under different levels of intensive culture. In Proceedings: Fourth Biennial Southern Silviculture Research Conference. Nov. 1986. GTR SE-42, SE For. Exp. Sta., Asheville, NC. 598p.

Shoulders, E. 1963. Root-pruning southern pines in the nursery. USDA - Forest Service Res. Pap. SO-5, 6p.

Snyder, E. B, R. J. Dinus, and H. J. Derr. 1977. Genetics of longleaf pine. U. S. Dept. Agric. For. Serv. Res. Pap. WO-33, 22p.

USDA 1974. Seeds of wood plants in the U. S. Agriculture Handbook. No. 450, USDA Forest Service, Washington, D.C. 883p.

USDA 1985. Southern Pine Nursery Handbook. USDA Forest Service, Southern Region, Atlanta, GA.

Wahlenberg, W. G. 1946. Longleaf pine: its use, ecology, regeneration, protection, growth, and management. 429 p. Wash., D.C.: Charles Lathrop Pack For. Found. and U. S. Dept. Agric. For. Serv.

White , J. B. 1979. Longleaf pine survival influenced by seedling size and length of storage. Proc. longleaf pine workshop, Mobile, AL, Oct. 17-19, 1978, USDA For. Serv. Tech. publ. SA-TP 3, SE Area S&PF (July 1979), 119, (P. 26-29).

Williston, H. L. and G. Screpetis. 1975. Managing for poles and piling. USDA For. Ser. So. Region, Atlanta, GA p24.